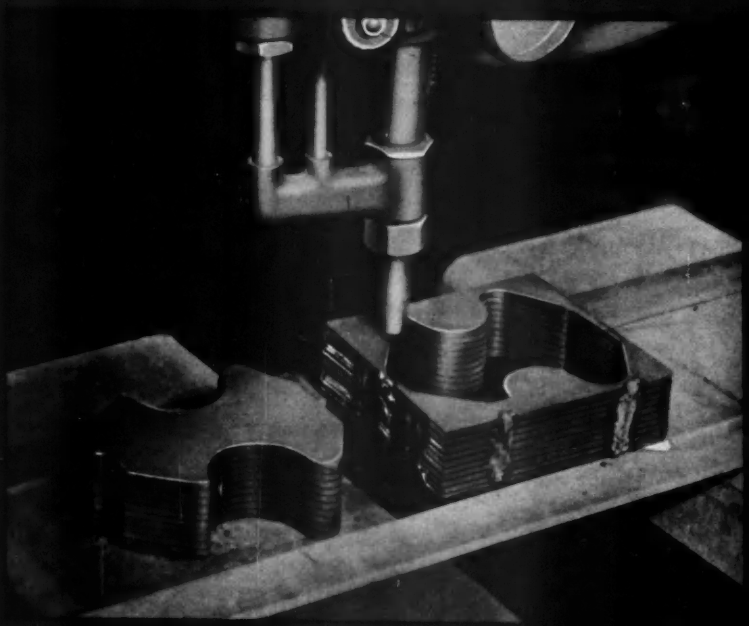
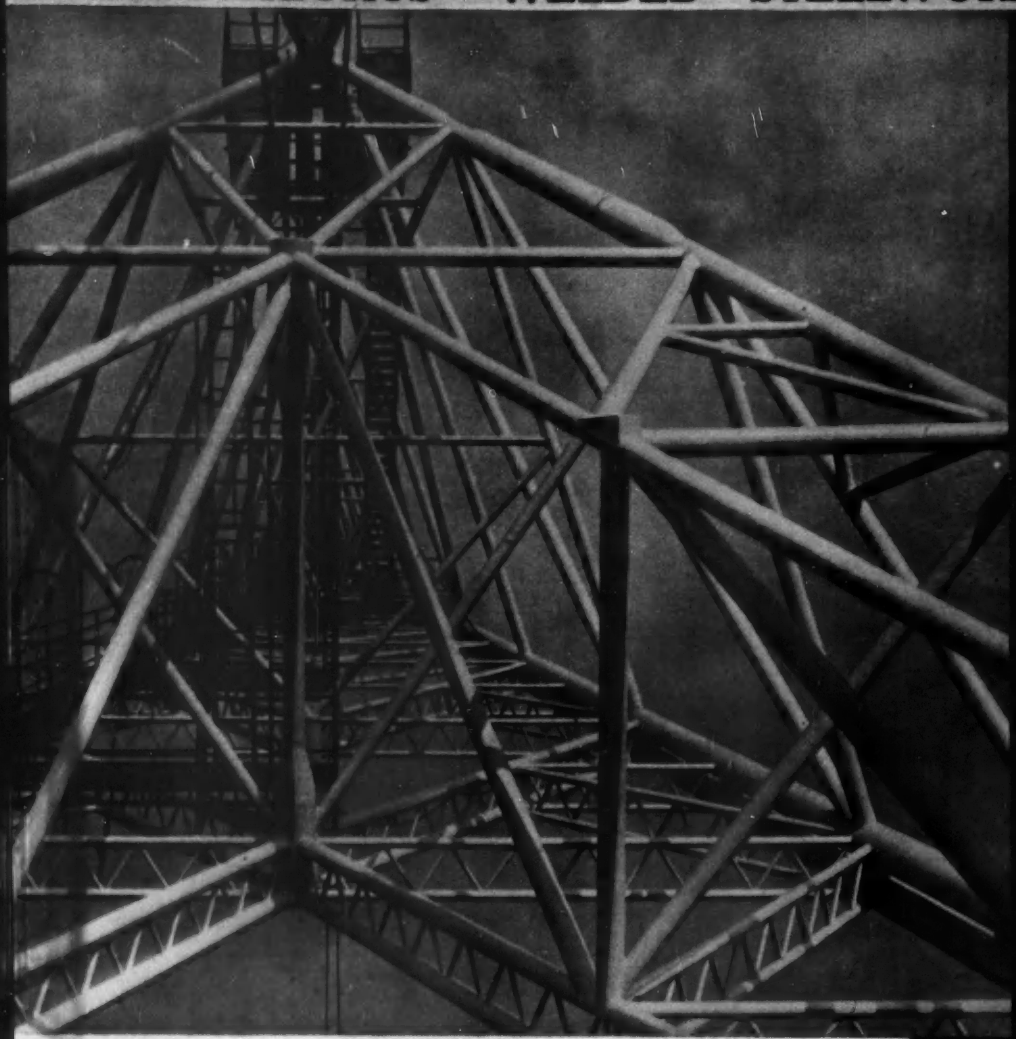
E DUOBUS UNUM

TRANSACTIONS OF THE INSTITUTE OF WELDING



'TUBEWRIGHTS' WELDED STEELWORK



Advances in design and technique

THE GREAT JIB

for the Rapier W.1400 Dragline.

The largest in the world, length 282 feet.

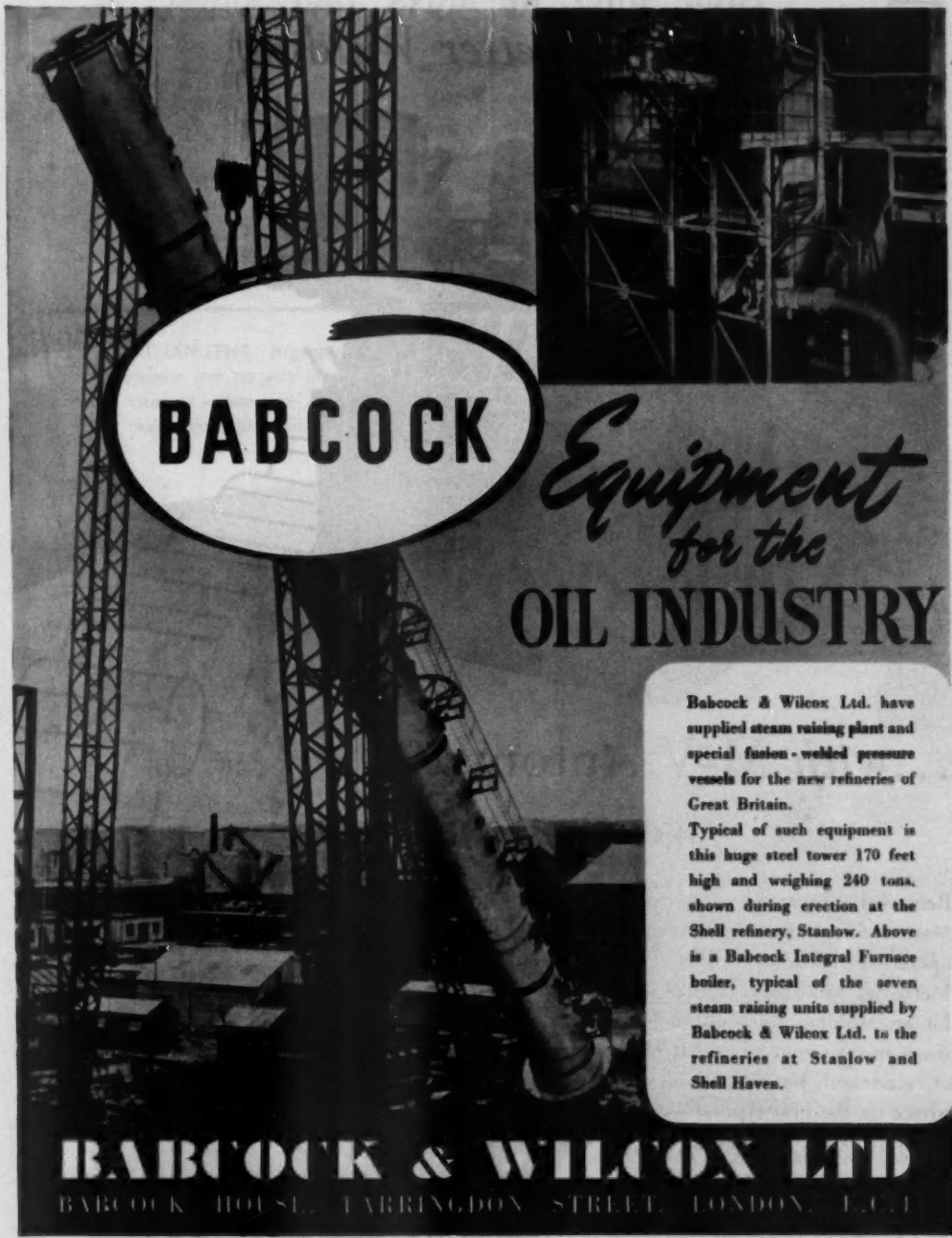
Minimum slewing radius 260 feet.

Bucket capacity 20 cubic yards.

TUBEWRIGHTS LTD.

EGGINTON HOUSE, 25 BUCKINGHAM GATE, LONDON, S.W.1. TELEPHONE: VICTORIA 0451

A subsidiary of Stewarts and Lloyds Limited



BABCOCK

Equipment for the

OIL INDUSTRY

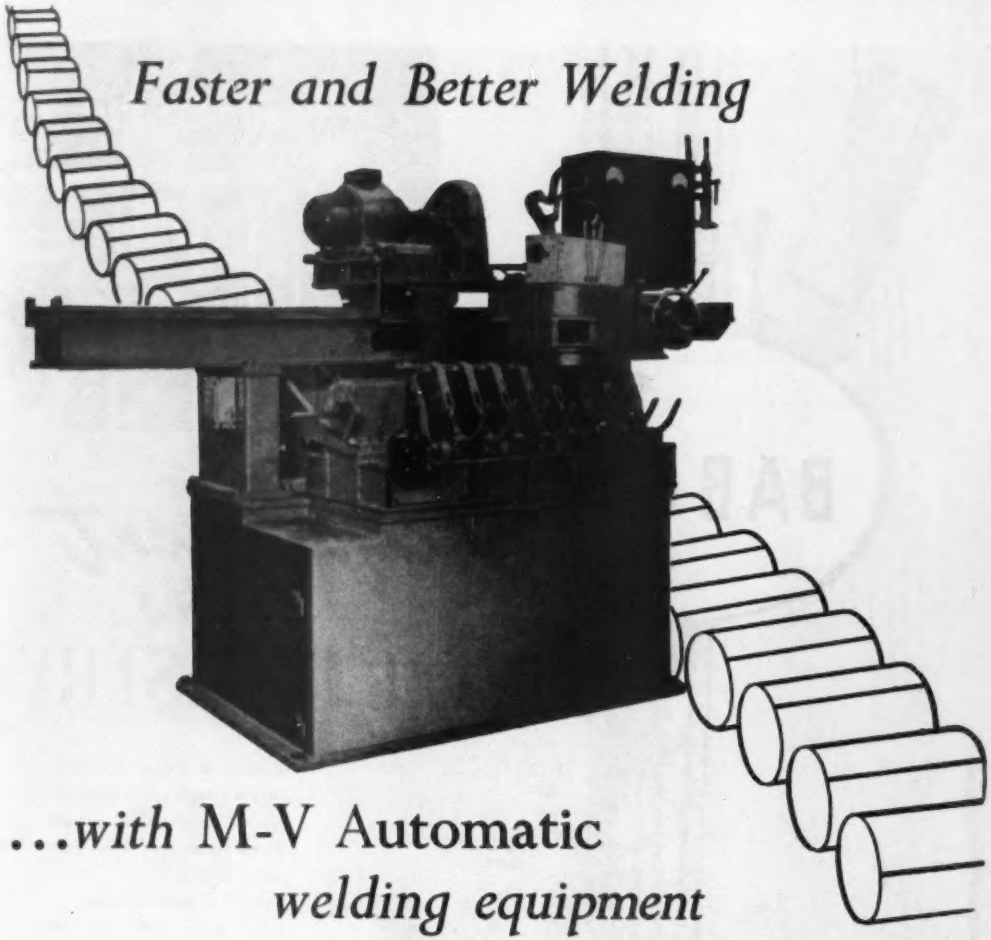
Babcock & Wilcox Ltd. have supplied steam raising plant and special fusion-welded pressure vessels for the new refineries of Great Britain.

Typical of such equipment is this huge steel tower 170 feet high and weighing 240 tons, shown during erection at the Shell refinery, Stanlow. Above is a Babcock Integral Furnace boiler, typical of the seven steam raising units supplied by Babcock & Wilcox Ltd. to the refineries at Stanlow and Shell Haven.

BABCOCK & WILCOX LTD

BABCOCK HOUSE, FARRINGDON STREET, LONDON, E.C.4

Faster and Better Welding



...*with* M-V Automatic *welding equipment*

Remarkable increases in the speed of welding are made possible by Metrovick automatic equipment. It is simple to use, economical in operation and the higher rate of output means lower production costs. Metrovick make many types of welding equipment, and also electrodes for arc welding. In addition M-V have one of the biggest welding shops in the country, so that M-V offer not only an unrivalled range of equipment, but also a wide experience in practical welding. For advice on the best type of welding equipment for any purpose consult Metrovick, the makers who use the plant they sell.

A Metrovick Automatic Atomic Hydrogen welding machine for cylinders with longitudinal welds.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD., TRAFFORD PARK, MANCHESTER, 17.

Member of the A.E.I. group of companies

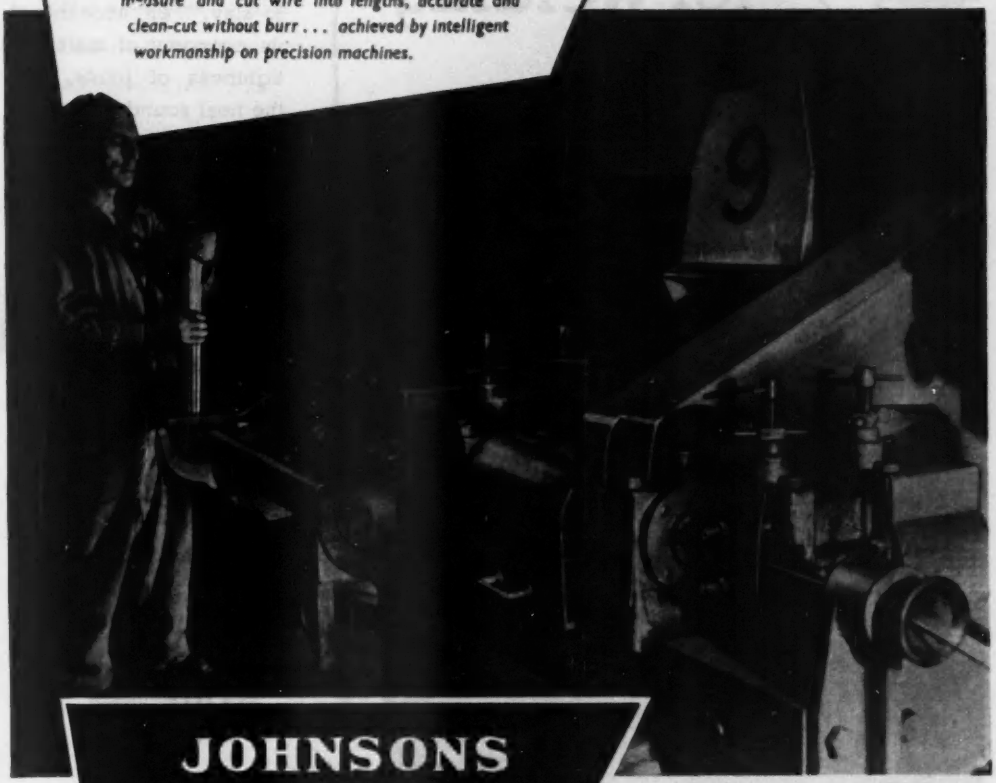
METROVICK *Equipment for More Efficient Welding*

1/6005

Have you pride in your work?

Naturally you have if you're a good manufacturer. Which means you are the type of person for whom Johnsons make welding wire. They make it carefully from first-class materials to meet exact analytical requirements. So when you buy Johnsons wire you buy **reliability** — and also something **extra** in the way of experience. The kind of experience Johnsons have been gaining — and putting to good use — for 178 years.

CUT LENGTHS. *High-speed machines straighten, measure and cut wire into lengths, accurate and clean-cut without burr . . . achieved by intelligent workmanship on precision machines.*



JOHNSONS WIRE . . . *FOR THE WELDING INDUSTRY*

RICHARD JOHNSON & NEPHEW LTD., FORGE LANE, MANCHESTER, 11.

APPLEBY PLATES for welding

Whether it be for bridges and other structures, for storage tanks, gas-holders, or for Class 1 pressure vessels and boiler drums, welded construction has "come to stay," on account of its economy of material, tightness of joints, and the neat sound job which welding makes.

Appleby Steel Plates have excellent physical properties, are ductile, flat, well-sheared, and will be found highly suitable to all forms of welded construction in which plates are used.

THE UNITED STEEL COMPANIES LTD

APPLEBY-FRODINGHAM STEEL COMPANY · SCUNTHORPE · LINCS

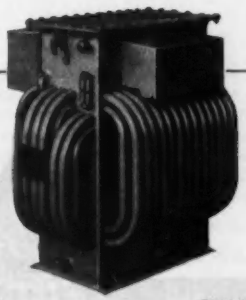
BRANCH OF THE UNITED STEEL COMPANIES LIMITED

TELEPHONE: SCUNTHORPE 3411 (9 LINES) TELEGRAMS: "APFROD" SCUNTHORPE

AF.67

Welding in Britain's shipyards

'ENGLISH ELECTRIC' multi-operator welding equipment is widely used in Britain's shipyards. Among the many ships which have been welded with the aid of 'ENGLISH ELECTRIC' multi-operator A.C. welding plant is the cargo steamer "City of Brisbane", shown in the illustration. This 12,500 tons vessel, which is an excellent example of British shipbuilding, was built for the Ellerman Lines by Cammell Laird & Co. Ltd. of Birkenhead.



'ENGLISH ELECTRIC'

multi-operator welding equipment

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Welding Department, East Lancashire Road, Liverpool, 10

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

WE.4

The OK Cadet

one hand operation

- Cuts Plates from ⅛ inch to 2½ inches thickness—CLEAN cuts.
- Will cut circles from 2 inch diameter upwards.
- Straight cuts of unlimited length.
- Cuts bevels.
- For use with acetylene—propane or coal gas.

Please send for O.K. Leaflet No. FC/C 52.

Another OK Product

WELDING SUPPLIES LIMITED

BEECHINGS WAY
GILLINGHAM, KENT

Phone Rainham (Kent) 81154 & 81600
Grams Weldsupply, Gillingham, Kent

MANUFACTURERS OF OK ELECTRODES

TRANSACTIONS OF THE
INSTITUTE OF WELDING

Vice-President: A. ROBERT JENKINS, J.P., A.I.Mech.E.

PRESIDENT - HOWARD J. THOMPSON, M.I.Mech.E.

Secretary: G. PARSLOE, M.A.

Honorary Editor: D. S. WATT, B.Sc., M.I.N.A.

VOL. 15 NO. 3 JUNE, 1952 PRICE 7s. 6d.

INSTITUTE NOTES AND NEWS

ANNUAL GENERAL MEETING

It has been decided to postpone the Annual General Meeting of the Institute from the date announced in the Calendar, which was Wednesday, 16 July, to the following Tuesday, 22 July next. It will be held as usual at the Institution of Civil Engineers at 2.30 p.m.

The Council's nominations for Honorary Officers and Council members in 1952-53 are as follows:

President, A. Robert Jenkins, J.P., A.I.Mech.E.

Vice-President, H. B. Fergusson, C.E., M.E.I.(Canada), M.I. Mech.E., M.I.N.A.

Honorary Treasurer, W. E. Harriss.

Representatives of Industrial Corporate Members, R. G. Ibraithwaite, M.I.C.E., L. Reeve, B.Sc., Ph.D., E. G. C. Trafford Willey, J. M. Willey, A.M.I.E.E.

Representatives of Fellows, Members and Associate-Members, C. A. Burton, W. Dunn, G. Foster, A.M.I.Mech.E., M.I. Loco.E., W. Heigh, M.I.E.S.S., A. J. Hipperson, B.Sc., W. K. B. Marshall, B.Eng., A.I.M., L. C. Percival, B.Sc., B.Met., J. Strong, M.A.

1952-53 PROGRAMME

The following are the provisional dates of meetings so far as already arranged for the session 1952-53:

8 *October*, 1952 ..	Presidential Address.
29 *October* ..	Two Papers on "Modern Developments in Industrial Applications of Resistance Welding," by Mr. H. E. Dixon, M.Sc., A.I.M., and another.
10 *December* ..	Paper by Dr. Nicol Gross on "Pressure Vessel and Pipe Welding Research."
29 *January*, 1953 ..	Annual Luncheon.
25 *February* ..	Sir William J. Larke Medal paper.
Thursday, 12 *March*	Joint meeting with the Institution of Structural Engineers. Paper by Mr. E. M. Lewis on "The Construction of the New Testing Laboratory of the B.W.R.A. at Abington."
Friday and Saturday, 24 *and* 25 *April*	Spring Meeting at Sheffield with Conference of Branch Officers.

All meetings are on Wednesdays unless otherwise stated.

FRONT COVER ILLUSTRATION.—Ten plates of mild steel cut and shaped in a single pass of the oxygen cutter . . . to identical measurements and with such a high quality finish that no subsequent machining is required. This operation—simple routine to the B.O.C. 36-in. cutter illustrated—saves time, labour and cutting gases, and permits quantity production to be carried on without loss of accuracy.

Apply to our local office for demonstration.

THE BRITISH OXYGEN COMPANY LTD.,
LONDON AND BRANCHES

PRINCIPAL CONTENTS

Institute Notes and News 67
Branch Officers and Committee for 1952-53 70
Automatic Welding 71
Winning Design for C. W. Hill Prize 88
Latest Additions to the Library 90
Abstracts from Recent Welding Literature 91

Published by

THE INSTITUTE OF WELDING, 2, Buckingham Palace Gardens, London, S.W.1.

The TRANSACTIONS of the Institute are issued free to Members. To non-members the price of this issue is 7s. 6d. per copy (by post 8s.).

The Institute of Welding is not responsible for and does not necessarily endorse statements made by Authors of Papers and contributors to the Discussions thereon.

SPRING MEETING

The Spring Meeting held at Glasgow from 24 to 26 April last was better attended than most of the Spring Meetings of previous years, about 140 members and guests joining in the whole or part of the proceedings. Attendance at the meetings on the Friday and Saturday morning was good and the discussion on each of the four papers was rewarding to the authors, as evidence of the interest which their papers had aroused. We hope to report these discussions fully in a later issue. Two of the papers were published in the April issue and a third is to be found elsewhere in this number.

Members were offered a choice of three works visits on the Friday afternoon and parties of about 30 went to each of the following: Sir William Arrol & Co. Ltd., John Brown & Co. Ltd., and Harland & Wolff Ltd. All the visits were excellently arranged and those who took part in them expressed their satisfaction at the interesting work which they had been shown.

On the Thursday before the meeting proper, a party limited to 27 visited the works of the Pressed Steel Co. Ltd., at Paisley in the morning, being entertained to lunch at the factory, and the Clydebridge Works of Colvilles Ltd., in the afternoon, where they had tea. These visits were extremely popular and the party could have been doubled in number if there had not been a limit imposed on it.

On the Friday night over 100 members and visitors dined together at the Rhul Restaurant. The Chair was taken by the President of the Institute and the principal guest was Baillie Taylor, representing the Lord Provost of Glasgow. Other guests included the officers of the West of Scotland Branch, the directors of the companies which had received parties at their works and the authors of the papers.

On the Saturday afternoon and evening over 30 officers of Branches met to confer on various matters of importance to Branch Committees.

The Institute is greatly indebted to the Officers and Committee of the West of Scotland Branch for the welcome which they gave to their visitors and their continuous co-operation in the planning of the meeting. We also owe thanks to the companies which received parties, to Mr. P. W. Thomas, the Secretary of the Institution of Engineers and Shipbuilders of Scotland, at whose premises the meetings were held and to the Lord Provost of Glasgow for his official welcome.

Finally, the ladies of the West of Scotland Branch must certainly not be forgotten in our thanks. They organised an attractive expedition to Rothesay for the lady visitors, but only one was forthcoming to take advantage of it.

VISIT OF DR. JAMES F. LINCOLN, E.E.

Dr. James F. Lincoln, E.E., founder and head of the American Lincoln Electric Co., addressed a private meeting of representatives of companies and firms belonging to the Institute and to the British Welding Research Association, at the Institution of Mechanical Engineers on 8 May last. Speaking on "Welding and Incentives," Dr. Lincoln first gave a brief survey of the present position of welding. He said that he thought that the future lay with automatic welding, in which he would expect to see very rapid development in the near future, possibly in the replacement of flux by an inert gas for the protection of the arc. He thought that the use of welding, the most modern and flexible tool for the joining of metals, had been hampered in particular by an excessive factor of safety and stressed the need for a new outlook. If it was possible for aircraft to be designed with a factor of safety of two, why did the authorities continue to insist on a factor of four for bridges and other structures?

Dr. Lincoln then turned to the question of incentive management, a subject to which he has given continuous study for very many years past. He said that a veritable revolution in human affairs could be brought about, if only we could release the latent ability in every individual human being, so that every man would go all out to employ the whole of his powers, instead of holding them back or leaving them unused as at present. Dr. Lincoln outlined the profit-sharing scheme operated by his own company, which he said had in eighteen years reduced the man hours per unit of production by more than 85 per cent. and resulted in their selling their products for less to-day than before the war of 1939-1945. In the last ten years they had paid an annual bonus to their workers averaging more than 100 per cent. of their basic salaries and wages. More important even than this was the addition to human happiness which came from the satisfaction of doing a job and doing it really well, the joy which a man realised when he was really using all his powers.

After his short address, Dr. Lincoln invited questions, which he answered very fully, mostly in explanation of the working of his company's scheme. A vote of thanks to the speaker was proposed by Mr. A. C. Hartley, C.B.E., and carried by acclamation.

After the meeting, Dr. Lincoln was the principal guest at a dinner at the Savoy Hotel, attended by members of the Council of the Institute and the British Welding Research Association.

GOTHENBURG MEETING OF I.I.W.

The International Institute of Welding is this year holding its annual meeting in Gothenburg, Sweden, from 7 to 13 September, by invitation of its Swedish member societies.

The first item on the programme is a meeting of the Governing Council of the Institute on 7 September. The following four days, 8 to 11 September, will be devoted to meetings of the fifteen technical Commissions composed of representatives appointed by the societies belonging to the Institute.

On the morning of Friday, 12 September, visits have been arranged to shipyards and other works in Gothenburg, and in the afternoon four papers on "Welding in Shipbuilding" will be presented by representatives of France, Great Britain, Sweden and the United States. The author of the British paper is Mr. H. H. Hagan.

The assembly closes with a meeting of the Governing Council on 13 September, after which those taking part will be free to join in a programme of works visits in Stockholm, Malmo and other industrial centres, organised by the Swedish member societies of the International Institute of Welding.

A full programme of entertainment has been planned for the benefit of delegates, including a reception given by the Gothenburg City Council on 8 September and a banquet given by the host societies on 11 September.

Full particulars of the meeting and enrolment forms may be obtained from Mr. G. Parsloe, Secretary-General, The International Institute of Welding, 2, Buckingham Palace Gardens, London, S.W.1.

Appointments Register.—Industrial Corporate Members may like to be reminded that a register of members seeking posts as foremen, supervisors, representatives, managers, designers, etc., is maintained at the offices of the Institute.

Employers seeking staff (other than welders) are cordially invited to inform the Secretary of the Institute of their requirements, and so assist the Institute to expand this valuable service to its members.

Fair Copying Declaration.—The Royal Society has recently issued a new edition of the pamphlet giving particulars of its Fair Copying Declaration, to which the Institute is one of the signatories. The Declaration permits a non-profit making organisation to make and deliver a single reproduction of a part of an issue of, for example, *Transactions*, or any other publication of the Institute to anyone who provides proper evidence that he requires the copy solely for purposes of private study or research. Copies of the pamphlet may be had from the Royal Society by any persons interested in it.

Offers of Papers.—Members of the Institute who are willing to read papers at meetings of the Institute or of its Branches are invited to send particulars to the Secretary for submission to the

Programme and Journal Committee not later than 15 June next. Where the complete text of the paper is not available, a short synopsis should be sent.

List of Welding Films.—A list of films on welding and allied processes has been compiled in the library of the Institute and is available to members, price 1s. 6d. (to non-members 2s. 6d.). The list contains the exhibition details and brief synopses of 73 films, which are classified under 13 subject headings. A simple reference system enables one to find the name and address of the suppliers of each film. The list should be very useful to teachers of welding wishing to find appropriate films on any given aspect of the subject.

Handbook for Welded Structural Steelwork.—The Structural Welding Sub-Committee, which has charge of the new edition of the *Handbook*, met to consider suggestions of members and others toward the end of May. It is not, however, too late for those who wish to propose changes, improvements and additions to send them to the Secretary of the Institute.

In the meantime, copies of the fourth revised edition are still available, price 10s. per copy, post free. This edition incorporates a number of important corrections to the formulae on pages 111-118 of the fourth edition. Members who have the original fourth edition are invited to apply to the Secretary for copies of the corrected pages, which will be supplied post free.

Binding of Transactions.—Arrangements have been made for the binding of members' volumes of *Transactions* in black embossed leathercloth at a cost of 10s. 6d. each, plus 1s. for postage and packing. Members wishing to take advantage of this arrangement should forward parts, with index, to Mansell (Bookbinders) Ltd., 41, Britannia Row, Essex Road, London, N.1.

Reprints.—Reprints of the following papers in *Transactions* are available at the prices named: R. G. Braithwaite and D. J. Davies, "Welding in Bridgework and Allied Structures" (paper, illustrations and discussion reprinted from the December, 1949, and February, 1950, issues, price 2s. 6d.); R. Weck, "An Account of M. Henri M. Schnadt's Ideas on the Strength of Materials and his Testing Methods" (reprinted from the April, 1950, issue, price 2s.).

Index to Transactions.—The index to Volume 14 (1951) of *Transactions* was published and bound in with the April, 1952, issue.

Conferences and Meetings.—The following are among conferences and meetings of which notice has been received at the Institute recently:

International Acetylene Association—52nd Annual Convention, Indianapolis, Indiana, 31 March to 2 April, 1952. Papers include some on oxy-acetylene welding and cutting.

Union of International Technical Associations—General Assembly, Paris, 27 May, 1952. An administrative meeting.

British Acetylene Association—Annual General Meeting and Annual Luncheon, Connaught Rooms, London, 12 June, at 12 noon.

Society of Chemical Industry: Chemical Engineering Group—in association with the Koninjlijk Instiuut van Ingenieurs: Chemical Engineering Section, and the Netherlands Chemical Society: Chemical Engineering Group—Conference on Fluidization Technology, 12 and 13 June, 1952, Connaught Rooms, London.

Deutscher Verband für Schweisstechnik EV—Exhibition of Welding Engineering and Great Welding Engineering Meeting, Essen, 14 to 29 June, 1952.

Institute of Physics—Fourth Industrial Physics Conference, Glasgow, 24 to 28 June, 1952.

British Welding Research Association—1952 Summer School on Welding, Ashorne Hill, nr. Leamington Spa, 16 to 25 July, 1952.

International Association of Bridge and Structural Engineers—Fourth Congress, Cambridge and London, 25 August to 5 September, 1952.

International Institute of Welding—Annual Assembly, Gothenburg, Sweden, 7 to 13 September, 1952. (See details elsewhere in this issue.)

Institution of Naval Architects—Autumn meeting in Italy, Genoa, Rome and Naples, 25 September to 2 October, 1952.

Société Française de Métallurgie—Journées métallurgiques d'automne, Paris, 20 to 25 October, 1952.

Further particulars of all the foregoing may be had from the Secretary of the Institute.

OBITUARY

We regret to record the death of the following members of the Institute: R. H. Connor—Associate-Member—Tyneside Branch; G. H. Field, C.B.E.—Member—Unattached; D. C. P. Willis—Member—Birmingham Branch; R. Downs—Associate Member—South Wales Branch.

Mr. Gordon Harvey Field was Director of Research of the aluminium laboratories of the Northern Aluminium Co. Ltd., at Banbury. He joined the Institute in 1937, when he had already over twenty yedrs' experience in the aluminium and aluminium alloy industry.

Mr. Willis, who was the son of J. B. Willis, associated with Sir Charles Parson in the construction of his first turbine in 1884, had a distinguished career in turbine development. He was apprenticed to Richardson, Westgarth and, after serving for twenty-three years with C. Parson & Co. Ltd., he joined the staff of the English Electric Co. Ltd., in 1946, where he remained until his death. He had many patent specifications filed in his own name and was associated with the first wind tunnel balance supplied to the R.A.F. Establishment at Farnborough in 1933. He was a lecturer at Rutherford Technical College, Newcastle, from 1924 to 1939.

BRANCH DINNERS

A further group of Branch dinners and social functions was held at the end of March and the beginning of April. First, on 27 March, the Wolverhampton Branch held its seventh annual dinner and ladies' night, with the Vice-Chairman of the Branch, Mr. E. Flintham, in the Chair. The principal guests were the President of the Institute, Mr. Howard J. Thompson, and the Mayor of Wolverhampton, Councillor James Beattie, J.P., both of whom spoke, responding to toasts proposed by Mr. Flintham. This is always an outstanding social function, and though it had been postponed from the date originally fixed, which was that of the King's funeral, the attendance was a new record at 450. Norman Nankervis and his orchestra provided dance music and there was a cabaret consisting of an exhibition of ballroom dancing by Keith and Hazella. The Branch and especially its Honorary Secretary, Mr. J. R. Thomas, deserve the warmest congratulations for a splendidly successful evening.

The Preston Branch held its second annual dinner at the Farmer's Arms Hotel, Preston, on 28 March. The Chairman was Mr. W. Hart, Chairman of the Branch, and the principal guests were the Mayor of Preston, Councillor J. W. Taylor, and Mr. Robert Jenkins, the Vice-President of the Institute. There was a good attendance and speeches were interspersed with an entertainment given by R. Frawley & Partners, which was much enjoyed. The toast of the Mayor and Corporation of Preston was proposed by the Chairman and answered by the Mayor, while Mr. Robert Jenkins replied to the toast of the Institute, proposed by Mr. A. J. Charnock, O.B.E.

The Manchester Branch held its annual dinner on 4 April at the Reform Club, Manchester, when there was an excellent attendance and the guests included Mr. Alfred Neate of the Ministry of Supply, the Vice-President of the Institute (Mr. A. Robert Jenkins) and Mr. H. West, Chief Electrical Engineer and Director of Metropolitan-Vickers Electrical Co. Ltd. The toast of the Institute was proposed by Mr. Neate and the response was made by Mr. Jenkins. Mr. H. West proposed the toast of the Branch, to which Mr. H. E. Lardge, the Branch Chairman, replied. Entertainment was provided by Mr. Graham Adam, the well-known north country illusionist.

BRANCH OFFICERS AND COMMITTEES FOR 1952-53

Below are the results of the elections in the Institute's Branches for officers and committees for 1952-1953, so far as is known at the time of going to press:

Birmingham

Chairman: C. L. Railton, A.M.I.E.E.
Vice-Chairman: E. Trafford Willey, T.D., M.I.Struct.E.
Hon. Treasurer: D. A. Impey, M.A.
Hon. Secretary: W. R. Harper.
Committee: E. V. Beatson, R. J. Fowler, B.Sc., A.M.I.Mech.E., A.M.I. Struct.E. (*ex-officio*), H. F. S. Gedge, H. V. Hill, M.Sc., A.M.I.C.E., S. N. Oxborrow, R. D. Watson, S. N. Wilkinson.

Eastern Counties

Chairman: I. McGregor (Norwich).
Vice-Chairman: W. Dunn (Colchester).
Hon. Treasurer: F. H. C. Biggs (Colchester).
Hon. Secretary: A. C. Stokes (Ipswich).
Committee: C. McL. Cameron, M.I. Mech.E. (Ipswich), J. A. Edwards (Colchester), P. S. Gaul (Colchester), A. T. Heath, M.I.Mech.E. (Ipswich), H. R. Hicks, A.M.I.Mech.E., A.M.I.P.E. (*ex-officio*) (Ipswich), F. Keating (Cambridge), J. Lewis (Ipswich), G. H. Smith (Norwich).

East Midlands

Chairman: M. A. Wells.
Vice-Chairman: W. L. Roe, M.I.P.
Hon. Treasurer: N. H. Carey.
Joint Hon. Secretaries: G. D. Earl, N. Hill.
Hon. Programme Secretary: A. R. Heaton.
Committee: C. E. Cobb, A.M.I.Mech. E., G. Drysdale, A.M.I.Struct.E., H. K. Ewen, A.M.I.Mech.E., L. Padmore, F. C. L. Poole, A. H. Scothern, T. D. Scott.

East of Scotland

Chairman: M. P. Henzell, A.M.I.E.E., A.I.Mech.E.
Vice-Chairman: R. D. Berry.
Hon. Treasurer: E. R. Roberts, A.M.I. Mech.E.
Hon. Secretary: A. G. Thompson, B.Sc., A.M.I.C.E.
Hon. Branch Correspondent: J. C. Adam.
Committee: W. McAdam, H. R. McKinstry, J. Stoddart, A.M.I.Mech.E., J. F. Wheeldon, D. W. Wright, R. M. Young.

India

President: Sir L. P. Misra, Kt.
Chairman: N. Daniel, B.Sc., A.I.C.
Vice-Chairman: B. N. Mohindra, B.A.
Hon. Treasurer: B. N. Majumdar, B.Sc., A.M.I.C.E.
Hon. Secretary: N. G. Chatterji.
Committee: S. Basu, B.Sc., A.M.I.E.E. (Ind.), J. B. Coleman, D. S. Desai, B.Eng., A.M.I.C.E., A.M.I.Struct.E., S. Ghattack, S. S. Mukherjee, T. R. Shields.

Leeds

President: A. J. Butterfield.
Chairman: J. Berry.
Vice-Chairman: C. Brass, A.M.I.Mech. E.
Hon. Treasurer: M. W. Parkinson.
Hon. Secretary: R. Archer.
Committee: J. H. Atkinson, E. E. N. Bernhardt, L. Catton, T. P. Gibbeson, W. Nicholls, W. Swan (*ex-officio*), W. J. Thaw, A. Tordoff.

Liverpool

Chairman: David G. Jones.
Vice-Chairman: Tom Williams.
Hon. Treasurer: A. E. Griffin.
Hon. Secretary: H. R. Cox, M.I.N.A.
Committee: G. Davenport, A.I.N.A., J. Day, E. Ford, E. J. Jefferson, G. A. O. Pridgeon, J. Maddick, G. Woodfield.

Manchester

Chairman: I. C. Fitch, A.M.I.Mech.E.
Vice-Chairman: R. Bushell.
Hon. Treasurer: A. E. V. Grosvenor.
Hon. Secretary: N. A. C. H. Beal.
Committee: E. J. Heeley, A.Met., F.I.M., F. Koenigsberger, Dipl. Ing., M.I.Mech.E., H. E. Lardge (*ex-officio*), L. H. Morgan, J. K. Mortimer, R. Partridge, A.M.I.Struct.E., J. A. Wright, B.Eng., A.M.I.E.E.

Medway Section

President: E. Seymour-Semper, M.I. Mech.E.
Chairman: L. A. Lidstone, M.S.E. (Mech.)
Hon. Treasurer and Publicity Officer: R. L. Gaughan.
Hon. Secretary: A. E. Harbord, A.M.I.N.A.
Committee: A. O. Barwell, A.M.I. Prod.E., E. S. Dodd, A.M.I.Prod.E., J. McPherson.

North-Eastern: Tees-side

Chairman: D. T. Smout, M.I.E.E., A.I.Mech.E.
Vice-Chairman: S. Walker, B.Com.
Hon. Treasurer: A. Jones.
Hon. Secretary: F. G. Batchelor.
Committee: G. Boyd, E. G. Clark, L. W. Cooley, F. Cox (*ex-officio*), C. E. Fenney, H. Gardner, J. W. Jackson, J. N. Parkin, T. Saunders.

North-Eastern: Tyneside

Permanent Vice-Chairman: N. M. Hunter, M.N.E.C.Inst.E. & S.
Chairman: C. Stephenson, M.I.N.A., M.N.E.C.Inst.E. & S.
Vice-Chairman: G. M. L. Logie, M.N.E.C.Inst.E & S.
Hon. Vice-Chairmen: J. A. M. Polson, M.N.E.C.Inst.E. & S., D. G. Springfield.
Secretary and Treasurer: T. S. Nicol.
Committee: J. A. Dorrat, M.I.E.E., G. Elston, G. W. Green, W. G. Greenaway, J. Henderson, A.M.I.Mech.E., A.M.I.Prod.E., H. Lander, W. Muckle, M.Sc.

North London

President: E. Ryalls.
Chairman: C. A. Burton.
Vice-Chairman: B. W. Silverwood, A.M.I.E.T.
Hon. Treasurer: E. Phillips, M.Sc.
Hon. Secretary: S. P. Bennett, M.Inst. B.E.
Hon. Programme Secretary: C. R. Thatcher.
Hon. Assistant Secretary and Correspondent: F. D. Hucklesby.
Committee: E. Buck, S. Byer, M.I. Mech.E., C. F. Davidson, A.M.I.P.E., B. C. Little, L. C. Percival, B.Sc., B.Met., F.I.M., S. M. Reisser, B.Sc.(Eng.), Dr. R. Weck.

Portsmouth

President: Rear-Admiral A. K. Dudley, C.B., M.I.Mech.E.
Chairman: C. R. R. Palmer.
Vice-Chairman: W. D. Dawson.
Hon. Treasurer: W. T. Farmer.
Hon. Secretary and Librarian: L. R. Eden.
Committee: F. A. Betts, M.I.Prod.E., W. A. Carter, H. W. P. Coles, A. C. Hart, W. J. Laskey, A. R. Soper.

Preston

President: W. Hart.
Chairman: G. Chadwick.
Hon. Treasurer: P. Baron.
Hon. Secretary: R. Robinson.
Committee: J. F. Breen, J. R. Handley, C. L. Hobbs, N. Leigh, F. Pilling, J. Watkinson, F. Westall.

Sheffield

President: A. Robert Jenkins, J.P., A.I.Mech.E.
Chairman: H. Townend, A.M.I.Mech. E.
Vice-Chairman: H. F. Tremlett, B.Sc., A.R.S.M., F.I.M.
Hon. Secretary and Treasurer: H. Stone, A.M.I.Mech.E., A.M.I.Prod.E.
Hon. Programme Secretary: K. Oldfield.
Committee: W. S. Acaster, C. W. Bower, A.M.I.E.E., A. Brewitt, R. E. J. Burgess, B.Eng., A.M.I.E.E., W. A. Jenkins, J.P., J. A. McWilliam, T.D., M.A., W. H. Stock.

(*concluded on page* 89)

AUTOMATIC WELDING

By J. LATIMER

This paper, highly commended by the examiners for the Sir William J. Larke Medal of 1951, describes the principal types of automatic welding machines now in use, comparing their relative merits and drawbacks, and from a detailed examination of certain applications to which hand welding might appear to have the advantage, concludes that length of run, size of joint, speed of actual welding and economy of electrodes are not the only important factors favouring the extension of automatic welding.

INTRODUCTION

Automatic Welding, as the term is generally used, applies to the fusion welding processes. It is in this sense that the term is used here.

Much has been written on the achievements of automatic welding and there is a general appreciation of its usefulness and range of application, although its limiting factors and associated problems are not so well known. This paper is an endeavour to point out the major problems in design and application and to consider some less obvious applications.

The paper is confined to automatic metallic arc welding and does not include the other processes, such as atomic hydrogen and argon arc. Many of the points discussed apply generally to automatic welding, but the main emphasis concerns the continuous electrode equipments, because of their wider fields of application and interest.

There are different types of automatic metallic arc welding, which can be generally classified as follows:

(*a*) The flux-controlled process, such as the gravity feeding of touch electrodes using electrodes of the same size and type as made for hand welding; and the "Firecracker" process, where again the flux coating determines the arc gap. The cut length of electrode used in this case is laid in the joint and the current is fed in from one end, the arc commencing from the other end. These processes have a limited use but lack the advantages of higher speeds and currents associated with the following two processes.

(*b*) There is the visible arc process, which has automatic motor-controlled electrode feeding mechanism and uses a continuous electrode of either bare wire, lightly fluxed, or heavy flux-coated electrodes.

(*c*) Then there is the submerged arc process, which has similar electrode feed mechanism and controls, but in which the molten pool and arc are not visible, being submerged in the powdered flux used. This process uses a higher welding current range, with relatively heavier depositions and higher welding speeds than the visible arc process. Joint preparation, in many cases, also differs from those permissible with visible arc processes.

Mention should also be made of the stick feeding machines, which have motorised feeding mechanism and automatic motorised arc control similar to the continuous coiled visible arc and submerged arc processes. Their main disadvantage is that the current that can be used, and consequently the deposition rate, are no greater than can be used and obtained with hand welding and their principal advantage is that any standard hand welding electrode can be used.

All these processes have their fields of application: some are more restricted than others and some are only economical on special applications.

Of the conventional processes used for general application, on plate thicknesses from $\frac{1}{8}$ in. up to about $1\frac{1}{2}$ in., the submerged arc process is probably the most economical and the fastest on the majority of applications. On plate thicknesses below $\frac{1}{8}$ in. the visible arc process is used on the majority of applications and in this range the welding speeds of the two processes are comparable. These ranges of plate thicknesses are not strict limits to the two processes, and there are applications in either range being done economically by the other process.

On plate thicknesses above $1\frac{1}{2}$ in. the submerged arc process has been used on a number of applications, and cylindrical pressure vessels up to 3 in. thick wall have been welded successfully. However, where multi-pass submerged arc welding has been done, insufficient information on results exists for a general statement of its suitability or economy. In support of this cautious note, interpass annealing has been found necessary on some heavy pressure vessels in America, and in this country visible arc has been found to be more economical than submerged arc on heavy section plates in certain applications.

The extreme accuracy in plate preparation required with submerged arc invariably demands machined plate edges, which are expensive on large structures of thick section, and can, together with the care required in set up, outweigh the advantages gained by higher speeds.

CONTROL EQUIPMENT

The control equipment of an automatic welder is that which replaces the skill and movements of the manual welder. It is worth noting how far this is achieved.

The automatic arc control, to be of value, should at least be comparable with the skill of the hand welder in following the characteristic fluctuations of the arc. In many equipments to-day the automatic arc control and feed mechanism surpass the skill of the hand welder in maintaining a steady arc length.

The main advantage of a stable arc is that it makes for better quality weld deposits, which might be briefly explained as follows:

There is an optimum arc length or voltage for any given electrode operating with a given welding current. It is highly desirable to maintain this optimum voltage. The metal depositing from the electrode tip, flux eruptions and gas disturbances in the arc make sudden variations in the arc length prone to occur at any instant. If the control can correct for these sudden changes and maintain a constant arc length, maximum heat continues to be concentrated into the area close to the pool, and, more important, the atmospheric contamination of the metal passing through the arc and also of that in the pool is minimised.

Although automatic controls can be more responsive than manual skill, no automatic control yet devised has been sensitive and responsive enough to correct faithfully all arc changes. There is always a delay in the electrode moving to correct the conditions and there are two stages in this delay, viz. (1) an initial change in any arc condition must occur to operate as a signal to the control; (2) after this there are additional delays due to the inertias of mechanical moving parts, gears, clutches, etc. There are also, in some equipments, the magnetic inertias of generators or motor fields, where time is required for the building up or the changing flux strength of magnetic circuits.

The initiating or signal circuits are usually highly responsive. Arc voltage relays can be made to respond to 0·5 volt variations in arc voltage, and electronic signal detectors or circuits can be made to respond to infinitesimally small variations in arc voltage. It will be appreciated that these highly sensitive signal detecting devices or circuits are of small value, if the subsequent mechanical and magnetic inertias are high, giving a sluggish response to the electrode movement. The reduction of these latter inertias is a major problem in design and development of automatic electrode feed mechanisms.

A comparison of a number of different arc control circuits and feed mechanisms is made later in the text, which will give a better idea of how different manufacturers have tackled the problems of getting a feed mechanism with a sensitive and high response.

Another essential feature of the control is that governing the

travel speed of welding. It is fairly widely accepted that the speed of welding or travel throughout the pass should be constant. Different passes may, of course, have different speeds. Manufacturers of automatic machines have usually designed their equipment with this procedure in mind. Now by comparison, the hand welder, because of varying joint preparation, varies his speed and sometimes the angle of his electrode to suit the immediate joint contour as he proceeds along the seam. In many cases of automatic welding, particularly by the submerged arc, it would be a big advantage to joint preparation to vary automatically the speed as the arc proceeds along the joint, more nearly emulating the hand welding procedure in order to suit immediate joint conditions and thus obtain an average higher speed. Devices have been experimented with and one or two have had a measure of success for particular cases, in measuring the amount of penetration and controlling the speed from this, but nothing very reliable or suitable for general application has been produced. It should also be pointed out that devices for measuring penetration, in addition to being complicated, will be costly, which is a further deterrent to their development. For the above reasons it should be appreciated that in this sense the automatic control falls short of the skill or ability of the hand welder, and it therefore becomes necessary to revert to the alternative of correct and unvarying joint preparation as an essential to automatic welding. If the preparation varies, the speed for the whole run has to be dropped to take care of the worst section of the joint. This, of course, applies particularly to single pass welds or the first run in multipass welds and hardly at all to subsequent runs.

Radiation pyrometers travelling along under the seam directly below the arc or metal pool can be a measurement of penetration. With many jobs this is impossible because of inaccessibility, but even apart from this in most seams it is impossible to guide the pyrometer accurately in the centre of the seam, or, more correctly, where it should be, under the hottest spot of the pool. The travel control in addition to this needs some indication of the joint condition immediately approaching the arc (which the above pyrometry signal does not give) to anticipate in some measure coming changes. This becomes more apparent with the higher speeds of welding. On some joints this indication might be roughly obtained by a light cell or cells on the underside, picking up arc light through the plate gaps immediately in front of the arc. Apart from the difficulties of keeping the light cell clean from dust and guiding it accurately, there is the main difficulty of co-relating this signal with the pyrometer signal to give the desirable control to the travel speed.

The travel motion is usually obtained by an electric motor driving through a gear unit to a table or rollers rotating the work, or driving a carriage carrying the welding head, the work in this case remaining stationary. A variation of speed can be obtained by any of the well-known variable speed devices; quite often a combination of two is used, such as a variable speed motor and a change speed gear box, to obtain a wide range of speeds with smooth, unstepped variation. Electronically controlled motors using grid controlled thyratrons form one of the latter arrangements used. Also hydraulic motors, some of which are available now, give wide speed ranges with stepless variation with almost constant torque.

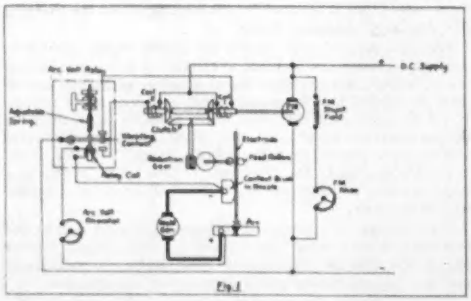


Fig. 1

An advantage of the electric motor for the travel drive is that it can be easily interlocked to start travel when the arc is established and to stop when it ceases, a condition often required.

A control which has often been thought very necessary on automatic equipments is one which will guide the head accurately in the centre of the seam, so as to avoid the necessity of accurate line-up of the job or relying on the operator to correct for alignment along the seam by a manually operated screwed slide or similar device. There are means that can be used in certain cases and

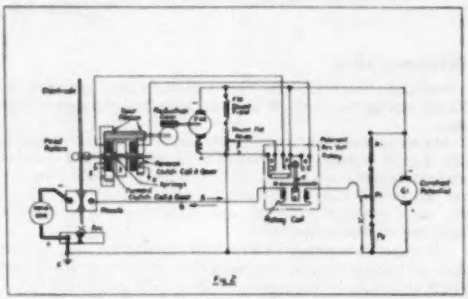


Fig. 2

which are fairly accurate only where the variation of joint from true alignment is gradual. There is, however, nothing suitable for general application, consequently no provision is made in standard controls and it must be accepted that to be fully automatic without the necessity of guiding, it is necessary to have accurate line-up of the job and the joint. On repetition jobs this should be a prime consideration in design and method of assembly, but quite often it is not. A point not often appreciated by users is that on the average fillet weld, for the electrode to be off centre by more than 1/16 in. results in a poor weld with lack of penetration on one side, and on small fillet welds below 3/16 in. less than 1/16 in. off centre will result in bad welds. This is a point which does not arise with hand welding, as the hand welder automatically guides himself by the joint and is quite often unaware of any deviations of it from a straight line.

There are usually a number of other controls incorporated in an automatic welding machine, for clamping devices, positioning, and sequencing operations. These, although important, are incidental to the main functions of the machine as a welder. They are also often peculiar to the particular type of machine or application and a general consideration would be difficult.

ELECTRODE FEED SYSTEMS

The systems described below are chosen from those which have been used by different manufacturers in standard marketed equipments and are therefore worthy of note in that they have had a fair period of trial. The fundamental circuits only are here described.

One of the main sources of mechanical inertia in an electrode feed system is the driving motor armature, since it usually has the highest rotational speed in the whole system. There is always great consideration given by designers to reduce its weight as much as possible, thus relieving the response of the control to overcome it. In most systems it is impossible to obtain the response of the system to correct for each load and speed condition, and the tendency to hunt on certain portions of the speed range becomes greater with the higher inertias in the drive.

One of the earlier methods, still in use, of reducing the drive mechanism inertia is to cut out the armature inertia completely by the use of a reversible friction clutch, magnetically operated, and controlled by the arc voltage. Variations of speed and reversal of direction of feed for the arc striking are effected by periods of clutch engagement in one direction or the other. The motor is set to run at a constant speed near the average feed speed required.

The arrangements shown in Figs. 1 and 2 are examples of this

type of system. They are two systems used for a number of years by two manufacturers in this country. They, or similar systems, have also been used by manufacturers in America and Europe. They have had a fair measure of success on different sizes and type of electrodes.

Referring to Fig. 1, the operation is as follows: The "arc volt relay" coil is connected across the arc in series with a rheostat which affords a means of adjusting the arc voltage. The contacts of the relay connect to the reversible magnetic clutch coils 1 and 2. These pull the clutch cones 1 and 2 respectively in contact with the clutch disc 3, which through a spur reduction gear drives the electrode feed rollers. The direction of feed depends on which clutch cone engages disc 3. A low arc voltage causes cone 1 to engage disc 3 and the electrode feeds upwards. A high arc voltage causes cone 2 to engage disc 3 and the electrode feeds down.

In normal operation the arc volt relay, which is a spring balanced relay, responds to about ½ volt variations and the vibrating contact alternates with short periods of contact between top and bottom fixed contacts on the relay. The aggregate periods of contact in any one direction in a given time determine the average speed.

The clutch cones 1 and 2 have their spindles solidly coupled together by non-magnetic shafting and are directly coupled and driven by the feed motor FM, which is set to a pre-selected speed by the shunt field rheostat FM Rheo. Serious hunting of the whole system takes place if the feed motor speed is not set somewhere close to the average feed down speed required, preferably slightly above. A change speed gear box is also used to obtain the speed range required for different electrodes and welding currents.

In Fig. 2 a sensitive polarised arc volt relay is used. Here again, the contacts of this relay P & Q connect to the coils of a reversible friction clutch 1 and 2. The coil of the relay in this case operates on the voltage difference between the arc and the constant potential across section X of the potentiometer P1. The constant potential is supplied by the generator G1. When the arc voltage becomes high compared with that across X, the current through the relay coil is in direction A, which causes contact P to close. This in turn causes clutch gear 1 to engage with the friction disc 3 and the electrode feeds down. If the arc voltage remains high, contact O also opens, inserting section Y resistance in series with the feed motor field and causing the feed motor to jump to a higher speed, thus feeding the electrode faster. A low arc voltage compared with X causes a current in direction B through the relay coil, which operates the reverse clutch gear 2, causing it to engage with the friction disc 3. This causes the feed rollers to reverse the direction of feed.

The clutch gears 1 and 2 are free to rotate on their common spindle and are both driven by a common pinion, coupled to the feed motor FM through a reduction gear. Friction disc 3 is keyed to the common spindle, so also is one electrode feed roller.

The speed of the feed motor is adjusted on the rheostat to be close to the average required. This is necessary to prevent serious hunting of the system. The addition of the step-up speed of the motor when resistance Y is inserted allows for a wider tolerance of pre-set speed but re-introduces the consideration of the armature inertia, although in this case it is not as serious as when the armature has to perform the whole of the speed variations.

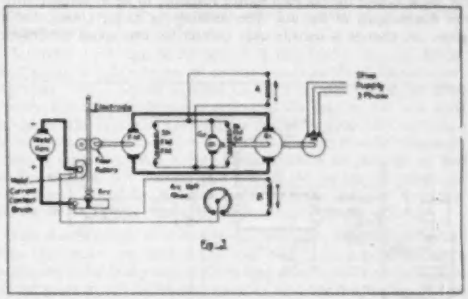
It will be noted in comparing Figs. 1 and 2 that in Fig. 1 the clutch is directly coupled to the motor shaft, whereas in Fig. 2 the clutch follows the reduction gear in the drive. This is purely a matter of choice in design. The reduced speed of the clutch in Fig. 2 is more or less balanced by the clutch parts having to be proportionately larger for the higher torques they have to transmit.

With this type of feed system the inertias of the feed motor armature are cut out or, as in the second case, largely reduced, but additional inertias of the clutch moving parts are introduced, and a still further delaying factor in response is the clutch slip, which is proportionately the same in both these cases at the feed rollers. For these reasons a good deal of care is necessary in the design of the clutch to endeavour to reduce slip, weight and the gap between contacting faces.

It is usually found in practice that a steady arc with some electrodes is obtained with the relay vibrating contact oscillating fast, making short periods of contact and consequently short periods of clutch engagement, whereas with other electrodes a slower oscillating movement and longer periods of clutch engagement are better.

Changing from one electrode size to another or a change in type of electrode often demands a skilful adjustment of the relay sensitivity, which usually lies outside the capabilities of the operator. Fortunately, most automatic machines when once installed continue to work with one size of electrode.

System Fig. 1 can be used with either alternating current or direct current welding supply. A rectifier is inserted in the arc control circuit with an alternating current supply. The system



shown in Fig. 2, because of the reversing current in the arc relay coil, can only be used with a direct current welding supply.

Another feed system which has had wide use in both Germany and America is one using a reversible variable speed feed motor with Ward Leonard type control. Figs. 3 and 4 show two different arrangements of this type of system. That shown in Fig. 3 has been used by a German manufacturer for a number of years. The feed motor FM shunt field is excited from the constant potential generator G2. The feed motor armature FM, which drives through a spur reduction (not shown) to the feed rollers, is directly connected electrically to the variable voltage generator G1. The generator G1 has a double field winding which induces opposing fluxes. Field winding A has a fixed excitation, being connected to the constant potential generator G2. Field winding B is connected across the arc voltage in series with the arc volt rheostat, which provides a means of adjusting the arc voltage. When the arc voltage is high the flux of field winding B predominates, causing the polarity of G1 to rotate FM armature in a feed down direction. When the arc voltage is low, field A predominates and generator G1 reverses its polarity, causing FM to feed back. When fields A and B are equal, FM armature is stationary, there being no voltage generated by G1. The magnitude of voltage generated by G1 determines the speed of feed in any direction. The feed speed therefore increases in accordance with the value of the arc voltage and does not have a series of impulses, as obtained on the reversible clutch system. The two generators G1 and G2 are coupled together on the same shaft with the motor M, which drives them, forming a composite machine.

The arrangement shown in Fig. 4 is one that has been manufactured for a number of years by an American company. The feed motor FM field in this case again has constant excitation, being supplied by the constant potential generator G2 and having resistances R16 and R17 and potentiometer R22 in series with it.

The feed motor FM armature drives through a spur gear train on to the feed rollers; it is electrically connected to the armature of generator G1 (usually through a reversing switch not shown). The field of G1 is excited by the voltage difference of the arc and the constant potential indicated by X, *i.e.*, the drop through the motor field, R16 and section of R22. G1 field is therefore only excited when the arc voltage is greater or less than X and the direction of excitation, and consequently the polarity of G1

armature and direction of rotation FM, are all determined by whether the arc voltage is greater or less than X. The arc voltage is pre-set or adjustable by the moving contact on R22. The generator G1 is driven by D.C. motor M1.

The main advantages of this type of system are its robustness, since there are no delicate relays or clutch wearing parts, and that compared with the reversing clutch type of system the initial arc signal (in this case in the form of a current through the field of generator G1), can be multiplied by the generator to effect a quick response of the feed motor which is proportional to the swing of the arc voltage.

The disadvantages are the inertia of the feed motor armature, and the magnetic inertia or delay in the build-up or alteration of the field of generator G1. The multiplied signal has to account for these delays for the feed motor response to be in keeping with the fluctuations of the arc. The multiplying factor chosen for a given arc change is usually only correct for one speed condition.

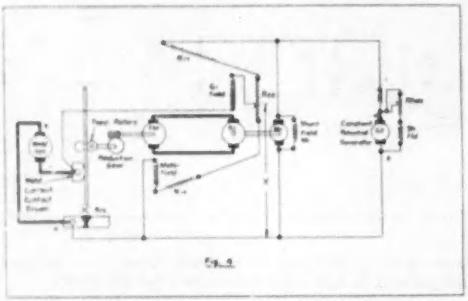


Fig. 4

The tendency will be to lag on higher feed speeds and to overshoot on lower ones before the correct speed is obtained. Any one setting is, therefore, good only for a limited range of speeds. Provision is, however, usually made in the circuit for altering either, or both, the feed motor field and generator G1 field, so that the response or effective amplification of the signal can be modified. By this means a fair range of electrodes and welding currents can be accommodated.

Comparing these two systems, that shown in Fig. 4 offers an easier means for altering the sensitivity and response of the system to given arc volt changes. It can, however, only be used with a direct current welding supply. That shown in Fig. 3 can be used with either alternating or direct current welding supply. A rectifier is inserted in the arc circuit when an alternating current supply is used. In Fig. 3 special care is necessary in the design of the generator G1 to prevent a transformer effect between the two field windings A and B. This effect, if present, tends to prevent any change in the field flux conditions and would, therefore, be a further delay in the response of the system.

There is also another advantage with this type of system, compared with the reversing clutch system in the mechanical design of the welding head, where it is the aim of all manufacturers to reduce the weight and size as much as possible. In this case a straight reduction gear between feed motor and feed rollers is all the mechanical drive necessary. With the earlier clutch system provision has to be made for housing and mounting the clutch coils and discs in the welding head.

ELECTRONIC CONTROLS

With the introduction of electronic controls to industrial applications it was to be expected that manufacturers would endeavour to use them for automatic arc welders, where the inherent higher sensitivity would be of great value. Successful controls have been developed and are now being used on standard equipments both in this country and America.

Compared with the previous systems discussed, the main advantages of this are, briefly: (1) Delays due to relay operation and build-up of motor and generator fields are eliminated. (2) The magnitude of amplification is directly proportional to the arc variation and the response can be made more nearly correct over the whole speed range, so that the inertia of the feed motor armature is of less importance and subsequent adjustment is not necessary for any change in electrode or current setting. (3) The circuit make-up facilitates easy modification, as for altering the multiplying factor or introducing corrections for hunting or similar unwanted effects. (4) The operator has only one control to adjust, namely, the arc voltage potentiometer.

An example of this type of system is shown in Fig. 5, which is one now being used in this country on standard equipment. Thyratron valves are used in controlling the speed and direction of the feed motor armature FM, which is coupled to the feed rollers through a worm and spur reduction gear.

Referring to Fig. 5, the feed motor FM shunt field has constant excitation from a direct current supply or rectifier (not shown). The armature FM is fed from transformer T1, through thyratron valves Th1 and Th2, which are connected back-to-back so that Th1 conducts one half cycle and Th2 the succeeding reverse half cycle of the alternating current supply from T1. The current from Th1 causes the feed motor FM to feed down and that from Th2 causes it to reverse and feed up. When the currents from Th1 and Th2 are equal in magnitude and duration, the forward and reverse impulses in the armature FM are obviously equal and the armature is stationary. When the currents through the two thyratrons are not equal, the armature rotates in the direction of the greater impulse and its speed is proportional to the difference of the two. Maximum speed in any direction is with one thyratron fully conducting for the whole of one half cycle and the other thyratron not conducting at all. The control which is described later is such as to vary the periods of conduction of each thyratron with the arc variations, so that the speed varies according to the arc demands.

The thyratrons used in this case are of the hot cathode mercury vapour type. It perhaps should be mentioned that a characteristic of a thyratron is that when the negative grid voltage is raised in a positive direction to its critical value where conduction commenced through the valve, the grid immediately loses control and cannot regulate or limit the current, even though moved back to its previous negative potential, so that the grid operates purely as a trigger on the firing of the valve. Conduction continues until the plate potential drops to zero or to a negative value and then the grid voltage can gain control again, a condition which applies each time the plate passes through zero potential at the

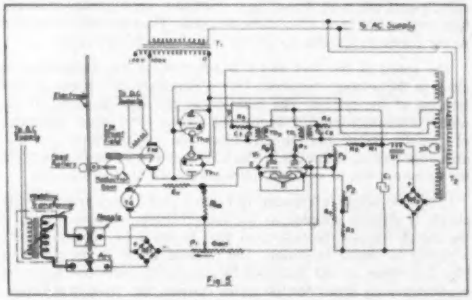


Fig. 5

end of each half cycle. The conduction or firing of the valve can be triggered off at any point during each half cycle by time delaying the raising of the grid potential with respect to the plate potential, appropriately known as phase shifting the grid potential with respect to the plate.

In this circuit, the phase shifting of the grid potential is accomplished by the use of transductors TD1 and TD2, a specially designed inductive component with a double winding, in which the reactance

of the secondary circuit is varied by varying the current in the primary.

It will be seen that the arc voltage to the control circuit is passed through a rectifier Rf1. Potentiometer P1 is very large compared with R10 and section X of P3, so that most of the arc voltage is imposed across P1 or to a slightly less amount across grids 1 and 2 of the double triode valve V1. The section X on P3 is the reference voltage or set arc voltage, which can be pre-set to any desired value. Whether grid 1 becomes more, or alternatively less, negative than grid 2 is determined by whether the arc voltage is less or greater than the reference voltage on P3. The total current through V1 does not vary; as the current on one side increases, the other decreases. If the arc voltage increases above the reference voltage, grid 1 instantaneously becomes more positive and grid 2 more negative, more current passes through transductor TD1, and correspondingly less current through transductor TD2. The effect is to reduce the reactance of the circuit associated with TD1 secondary and in consequence the grid of thyratron Th1 becomes

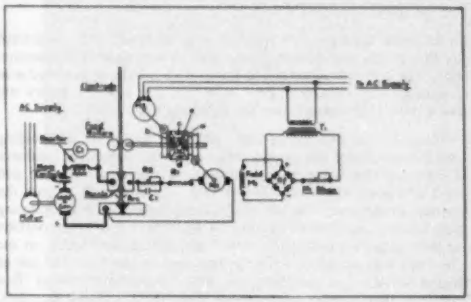


Fig. 6

more in phase with its plate potential and a longer period of conduction takes place during the feed down half cycle. The reverse is the case with Th2 and it therefore has a correspondingly reduced period of conduction. The nett result is that the feed motor accelerates to correct for the increase in arc voltage.

The other components shown are incidental to the main function of the circuit. The Tacho Generator T9 operates as a stabiliser in the arc circuit and C1, X1, R1 and R2 are part of the smoothing circuit of the rectified direct current supply.

This system of control can be used with either alternating or direct current welding supply.

Finally, in considering feed systems and controls, one arrangement which is worthy of note from the standpoint of reducing the mechanical inertia and giving a wide speed range is that of using a differential drive with two feed motors. The system described below in Figs. 6 and 7 was being used in Russia in 1940, and a similar system, I think, is now being used in America on inert gas welding equipment.

Referring to Figs. 6 and 7, the drive is the same in both, but the electrical control of the feed motor M1 differs.

To describe the system, refer to Fig. 6. Of the differential gears comprising bevels *a*, *b*, *c*, *d*, planetary gears *c* and *d* are free on their respective spindles, which in turn are carried by the centre block frame *e*. This block frame *e* forms part of the feed roller spindle. Gears *a* and *b* are also mounted on the feed roller spindle but are free to rotate on it. Gears *a* and *b*, however, are solidly coupled to two worm gears, which are driven by two worms mounted on shafts of feed motors M1 and M2. M2 is an alternating current constant speed motor. M1 is a variable speed direct current motor, whose armature is energised by the arc voltage and its field is constantly excited.

When the speeds of M1 and M2 are equal, gears *a* and *b* drive *c* and *d* equally, so that the latter rotate on their spindles as shown by the arrows, and frame *e* remains stationary; consequently the feed roller does not rotate, the motors balancing each other. With the appearance of a high arc voltage M1 speed exceeds M2; *a* and *b* now drive *c* and *d* unequally and the difference of the two motions causes frame *e* to rotate and the feed rollers rotate in a feed down direction, tending to correct the arc length. The feed roller speed and direction depend on the relative speeds on M1 and M2.

The ratio of *c* or *d* to *a* or *b* is 1 : 2 and worm gear 10 : 1, so that about 10 r.p.m. variation between M1 and M2 causes 1 r.p.m. of the feed rollers. It will be appreciated that mechanical inertia is reduced to a minimum when such a small variation in motor speed produces 1 r.p.m. difference of the feed speeds. With the previously discussed systems to produce the same variation of feed roller speeds, *i.e.* 1 r.p.m., a motor speed variation of from about 100 to 120 r.p.m. is necessary.

A further advantage of the system is that feed motor M1 lends itself easily to other forms of control, such as Ward Leonard or electronic. Fig. 7 shows a Ward Leonard control circuit for this system. The arc voltage varies generator G1 field in this case and the generated voltage of G1 supplies the feed motor M1 armature. An amplification of the arc voltage variation can thus be obtained, giving a quick response to M1. The direction or polarity of the field of G1 does not change, as it does in the systems described in Figs. 3 and 4, and for this reason the magnetic delay or magnetic inertia of the field is relatively smaller than in those systems.

The disadvantage of this system compared with the previous ones considered are mainly physical. The welding head is much larger and more bulky with the two feed motors and also the whole of the gears in the differential have to take the full torque of the feed rollers, which makes them relatively large compared with much of the gearing in the previous systems. It is also advantageous to have the motor capacities large enough, so that any serious speed regulation with load does not occur.

For open circuit striking conditions an additional resistance (R2 in Fig. 6 and R1 in Fig. 7) is inserted to limit the current from the arc voltage supply. Immediately a current is established in the arc, the reactor volt drop causes contactor C1 to close, cutting out this resistance. The lower voltage of the arc is then imposed directly on to the control.

Both the systems shown in Figs. 6 and 7 are suitable for use with alternating or direct current welding supply.

The control systems just described are fairly representative of those in use. There are, of course, others and there are a number of patented systems which might appear to be equally suitable.

ARRANGEMENT OF FEED MECHANISMS

Before leaving feed mechanisms and controls, mention should be made of their arrangement. It is usual in standard equipment to split them up into three or four different units, intended to be convenient for mounting on any arrangement or type of machine. It also enables them to be built in quantity and stocked for convenience of quick delivery. The arrangement of these units although fairly standard now is, of course, always open to dispute,

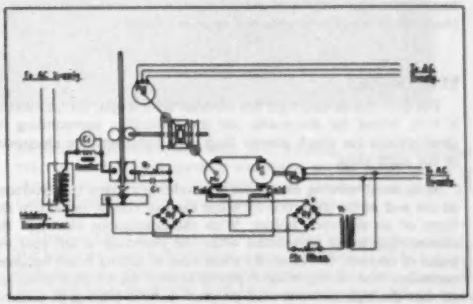


Fig. 7

and there are a number of users who find they cannot conveniently use the standard units for their projects. This is particularly true of the "operator's controls" units.

The different units generally comprise (*a*) the welding head, (*b*) the operator's controls, (*c*) the main electrical contactor panel, (*d*) the control supply unit.

(*a*) The welding head usually contains the whole of the electrode feed mechanism, including the feed motor, and clutches when they are used. It also has a nozzle directing the electrode to the work, which usually contains the welding current contacting brushes. For the heavier electrodes an electrode straightener is mounted at the top of the head, guiding and straightening the electrode into the feed rollers and nozzle. There is also some means of adjusting the direction of the nozzle, so as to guide the electrode into the seam. This adjustment, in some designs, moves the whole head; in others, a section of the head only with the nozzle. The weight and size of the welding head could be reduced without this adjustment. It appears, however, to be necessary on most applications and has come to be regarded as an essential feature of the welding head. It could be provided for separately but the overall size would probably be increased. Other fine adjustments such as vertical and horizontal adjustment often fitted to machines are not considered essential portions or features of the welding head. They are provided for separately as separate slide components attached to the head or head mounting.

(*b*) The operator's controls as a standard unit are usually in the form of a panel which can be mounted conveniently for the operator. It contains all the switches, control rheostat, etc., for the different machine operations.

On some equipments the controls, or some of them, are mounted composite with the welding head, with others in a panel separately. This arrangement is convenient for a large number of applications, but if adopted as standard debars applications where the space for the head is restricted and where it is necessary to control at a distance from the head.

On many machines it has been found convenient to depart from the standard panel and split the controls up, mounting them or some of them separately.

(*c*) The main electrical contactor control panel containing all the electrical apparatus is usually in cubicle form for either wall or floor mounting, whichever is thought more convenient.

(*d*) The control supply unit usually takes the form of a separate M.G. set or rectifier unit, supplying a low voltage direct current (60 to 100 v.) for the whole of the control circuit, direct current supply being preferred for the variable speed motors. The low voltage is necessary, as most welding heads have to be insulated from earth to prevent shorting the welding current supply, hence the feed motor and clutch coil casings cannot be earthed. It therefore becomes necessary to use a low voltage on them for safety.

A full appreciation of the various control components makes it possible for any user or prospective user to plan the arrangement of his own machine and more co-operative guidance and instructions can be given to the machine maker. Manufacturers of automatic machines quite often are not informed of the production line system and routing of components, and therefore guidance of this kind in machine layout is a great assistance.

ELECTRODES

The continuous electrode has obvious advantages, but in making it fully fluxed for automatic use the difficulties surrounding its development are much greater than with hand welding electrodes of the same class.

With hand welding electrodes the welding current is introduced at the end of the electrode by some kind of clamp, usually in the form of an electrode holder. With the continuous electrode the current has to be introduced while the electrode is fed past the point of contact, consequently some kind of sliding brush becomes necessary. The sliding brush is placed as near the arc as practicable, so that the high currents used produce as little heating as possible in the length of electrode before the arc.

Bare electrodes as used with submerged arc and bare wire visible arc welding (the latter is still in use on some automatic applications) present relatively little difficulty with the sliding contact, as the whole surface of the electrode can be used for contacting the sliding brush. There is, however, still a limit to the current that can be passed with these electrodes, depending on the size or area of the brush and the pressure applied to it, and on the cleanliness of the surface of the electrodes.

With the flux-coated electrode for automatic welding the major design problem is that of feeding the current into the core wire from sliding brush contacts on the outside. The flux coating itself is non-conductive. Various arrangements have been tried, such as making the core wire a steel tube with the flux inside the tube, wrapping the flux on in the form of a tape immediately before the arc and after the sliding current brush, and slotting the flux coating of the electrode, with brushes contacting the core wire through the slot. The present, more popular arrangement is to place a spiral wire or braided wire on the outside of the core wire and compress the flux into the spaces between the spirals. The current is passed from the sliding brushes to the core wire *via* the spiral wrapping wire.

All these constructions leave part of the core wire uncovered by flux with a consequent greater risk of atmospheric contamination. The last-mentioned construction with the spiral wrapped wire minimises the uncovered core wire and the exposed ridges are fairly evenly distributed over the electrode surface.

However, the solution of the problem of feeding in the welding current introduces the second major problem, which is to achieve a sufficient flux covering for complete protection of the arc and pool of molten metal. The fins or spin wire employed to pass the current to the core wire being of necessity metallic and becoming part of the weld deposit require an additional flux in proportion to their quantity, but at the same time they occupy space on the electrode that would normally be occupied by the flux. The use of higher currents in automatic welding necessitates heavier flux coatings than would be required with hand welding currents, so the problem is aggravated.

The solution to this dilemma necessitates the use of a double layer of spiral wires or braid or the use of a specially shaped core wire.

The above points describe some of the added difficulties in developing continuous fluxed automatic electrodes. Notwithstanding these difficulties, standard automatic electrodes are being made using currents of the order of twice those used for hand welding for a given size of electrode.

It is unlikely that continuous fluxed electrodes will be made in larger sizes than with 2-gauge core wire for the following reasons:

(1) Electrodes of a larger diameter than 2-gauge become increasingly difficult to make. The flux coating is subjected to a much greater amount of stretching and compressing than on the smaller diameter electrodes, when coiled on to and unwound from a spool of reasonable size.

(2) The welding head feed mechanism needs to be more powerful and consequently larger to pull the electrode off the reel, straighten it and push it through the current contacting brushes. This would make the welding head larger and the mechanical inertia of the moving parts higher, adding problems and limits in design and application.

While many of the difficulties cited above for continuous fluxed electrodes do not apply to submerged arc electrode development, there are difficulties associated with the flux of this process, both in use and in storage. It must also be remembered with this process that there are other difficulties associated with guiding the electrode in the seam under the flux pile.

For submerged arc welding the currents used for a given size of core wire are about 5 to 8 times those used for hand welding.

It should be pointed out that on at least half the applications it is impossible to use the maximum current of which the electrode employed is capable. This is true both of submerged arc and of

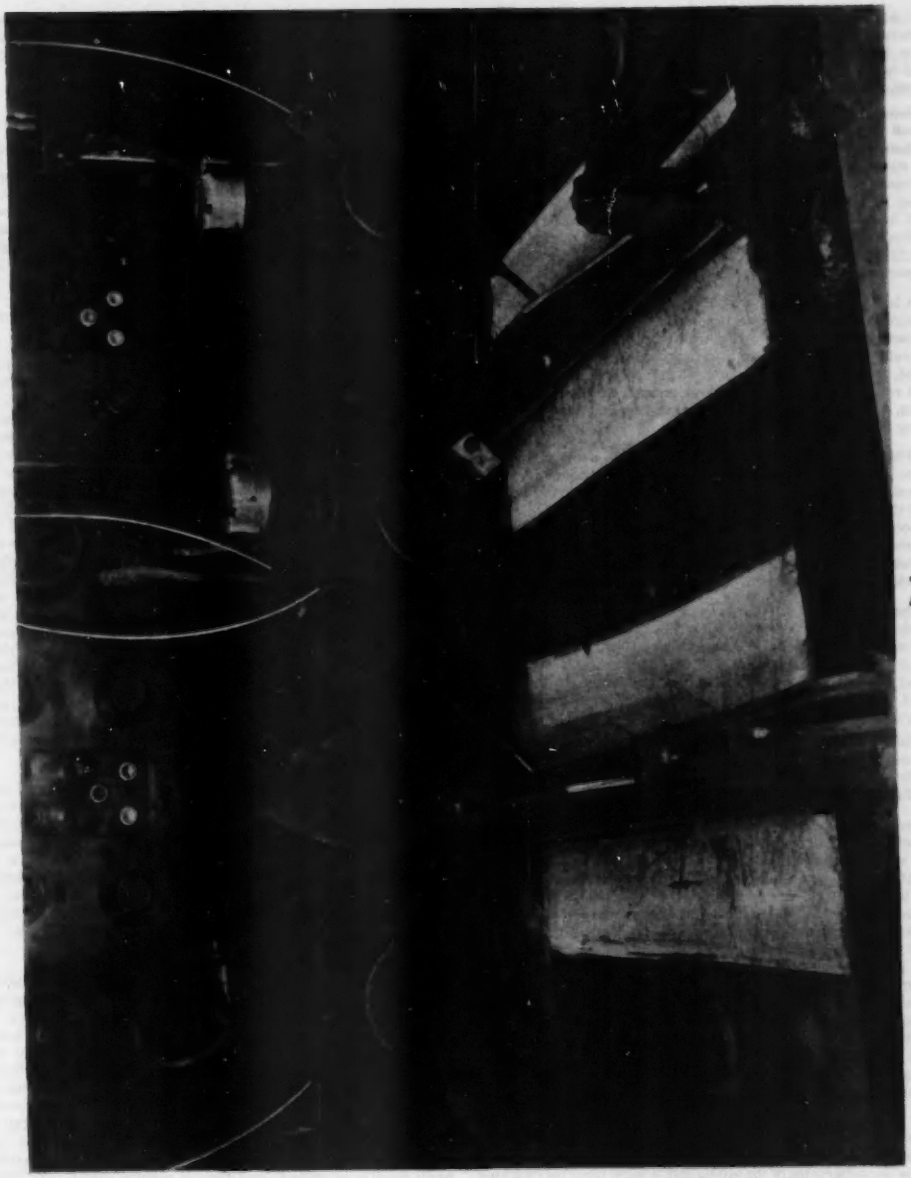


Fig. 8

continuous fluxed electrodes; this limit is set by the joint preparation or material thickness forming the joint and not by the electrode.

The relatively high cost of production of special electrodes, such as stainless and high alloy steels, is one of the main deterrents to their development and manufacture. It is in this field that the stick feeding machines using standard type hand welding electrodes will perhaps in future prove most economical.

APPLICATIONS

In the application of automatic arc welding there are a number of limitations not experienced with hand welding. To begin with there are no continuous automatic electrodes so far made which are capable of welding in the vertical or overhead positions and consequently machines have never been developed.

There is again a limit to the size of fillet that can be welded in the horizontal vertical position; a position which is often required. This limit is a fillet size with approximately $\frac{1}{2}$ in. leg. Above this size, with most electrodes, both hand and automatic, it is of course impossible to hold the pool in a central position and the results

are odd legged fillets falling towards the lower plate, but with automatic it is impossible to weld multipass fillets in this position, as is done by hand welding, without a serious reduction in speed and welding current, so forfeiting any advantages over hand welding.

Joints, both fillet and butt, have to be more carefully prepared. Small gaps between plate edges which can easily be negotiated in hand welding are a source of trouble and usually loss of speed in automatic welding. To make full use of the higher speeds obtainable with automatic welding, joints should be consistently close fitting throughout their whole length and, where possible, well backed. With veed butt joints it is often necessary to put a sealing run in at the back of the vee first, to form a backing for the first run of automatic welding. Also machined U or double U preparations are often a necessity.

A further consideration which has to be given to joint preparation is that the joint must be lined up with the run of the welding head. If there is a divergence of the two, more work is thrown on the operator in correcting it, or mechanical guiding devices have to be fitted, and these are only good where the divergence is gradual and relatively small. These devices, in addition to increasing the price, will also increase the bulk of the welding head, which, in many cases, would be inconvenient.

With vertically undulating or inclined joints rising gradients of up to about 1½ in. in 24 in. can be welded. It becomes more difficult to hold large pools on such gradients. The preparation of the joint and the type of electrode used are factors affecting this limitation. A point not always appreciated, however, with automatic machines is that between certain limits the arc can follow a joint rising or undulating in a vertical plane towards or away from the electrode nozzle. The space under the nozzle tip is the only limiting factor.

The capability of an automatic arc in welding successfully over sudden obstructions, such as tack welds, depends on the sensitivity and response of the feed mechanism and control, and also on the speed of travel along the joint. It is not practicable to vary the speed when welding over such obstructions, as might be done in hand welding. Consequently care in preparation has to be taken with such obstructions.

The following examples have been particularly chosen to demonstrate some factors which can determine the economic application of automatic welding where the actual speed of welding or deposition is of secondary importance.

Long straight butt or fillet welds, whether longitudinal or circumferential, are obvious choices for automatic welding, so also is a small job whose seams can be fed through continuously under a welding head or in large clamped batches, making in effect one long seam; but consider the case of the welded plate girder. Its construction is well known and does not need illustrating. In order to restrict distortion during welding and also to facilitate easy fitting, the transverse stiffeners are placed and tack welded into position before heavy welding on the flange-to-web fillets commences. The fact that the transverse stiffeners are in position prevents a continuous run on the flange-to-web fillets with an automatic machine. With fillet sizes above ½ in. leg only one head can be used and the weld has to be positioned for a down-hand weld. Consequently, to minimise distortion, the procedure will necessitate a series of turnovers of the girder to weld alternate sections on each side of the web.

At each transverse stiffener the head has to be raised and lowered into the next section. To do this efficiently demands a motor operated or air cylinder operated head slide. Because also of the dimensions of the nozzle and in some cases the clearance required on the head, automatic welding cannot commence or finish right at the corners of each transverse stiffener. On shallow stiffeners less than 4 in. deep a nozzle clearance of at least 3 in. from each corner is required; on deep stiffeners a head clearance of approximately 9 in. is required. The welds from these clearance points into the corners have to be done by hand welding.

On submerged arc welding the clearances are higher because of the flux nozzle size.

The welding of the stiffener-to-web fillets has similar limits, but in addition, for fillet sizes above ½ in. leg, where the girder has to be tilted to present a normal down-hand weld, welding is impossible on all except short girders, being limited by the shop head room and the available adjustment of the automatic welding head.

When all these various points are considered, together with the advantages of speed with automatic welding, it will generally be found on a time basis that there is an economic limit of a run length of about 4 ft. between stiffeners. Below this length of run it is uneconomic to use automatic welding. This is almost irrespective of electrode and fillet size. Consequently there is little to be gained in automatic welding a girder with, say, 5 ft. spaced stiffeners. On deep stiffeners, where head clearance instead of nozzle clearance is required, the economic minimum will no doubt be higher, probably about 6 to 7 ft. between stiffeners. This, of course, is a general conclusion which can only be taken as a guide.

An exception to the above is where distortion is a problem and where automatic welding is adopted purely to minimise it.

As an example of a similar type of joint on a different structure, consider the welding of tee and angle stiffener bars on to railroad mineral wagon bodies, as illustrated in Figs. 8 and 9. Owing to the size and type of jig required to hold the job with its possible inaccuracies and difficulty of locating and clamping the stiffeners accurately, the economy of automatic welding at first seemed doubtful. Furthermore, the possible increase in welding speed or deposition rate by automatic welding was not particularly encouraging. As shown later in the text, the estimated hand welding time for each 40 in. long pass was six minutes and the automatic welding time was five minutes. In this case the welds are ¼ in. fillet (leg length) and the length of run is 40 in. The machine illustrated consists of a motor operated rotating jig on to which the folded "U"-shaped end of the wagon body is located and clamped, as shown, together with the stiffener bars which are also located by the clamps. The jig is indexed so that it turns through 90 deg. with each operation of the push button. A gantry carriage straddles the jig and has a transverse track, on which are mounted two travel carriages, each carrying a pair of automatic welding heads with their necessary positioning adjustments. The travel carriages are motor driven and have indexing limit switches, enabling a number of different settings of the heads to be obtained quickly for the different positions of the stiffener bars.

The gantry carriage is motor driven at welding speed, and also has a high positioning speed of 26 ft./minute. The gantry carriage has to be run off clear of the jig (as shown in Fig. 9) to enable the latter to be turned to a new position. One of the detrimental features of the machine is that it is impossible, in the space, to get all the heads on one starting line, so that the left-hand heads have to be started first, and then, when approximately a foot of weld has been done, the right-hand pair. Thus the actual welding time is prolonged, but even so the time for the run shown is 4·50 minutes.

Now to compare welding the same run of four welds by hand, using the same jig. The estimated hand welding time using 4-gauge electrodes for each 40 in. run is 6 minutes. The tee bars are 2 ft. 9 in. apart. In the small area it is impossible to get four hand welders each welding one run of weld. Two operators are the most that can be accommodated without getting in each other's way, consequently the total hand welding time, if both operators start and finish together, is 12 minutes. With the automatic machine the total welding time is 4·50 minutes and one operator only is used. At the completion of the welds on one side, the hand welders would have to move off the jig (just as the automatic heads have to be moved), and there is nothing gained from hand welding in the changeover, except that lining up the heads to commence the weld run can take up to approximately one minute longer than a pair of hand welders take to commence welding; but it is doubtful how consistently hand welders could work throughout the day in starting to weld immediately the jig is turned. The size of the job does not lend itself to a close control of a hand welder's movements in this way. However, compromising and conceding half-a-minute quicker start with hand welding on each turn of the job, the difference in time is now 12 minutes to 5 minutes, a saving by automatic of 7 minutes. There are three sides to be welded per component, so that the total saving per

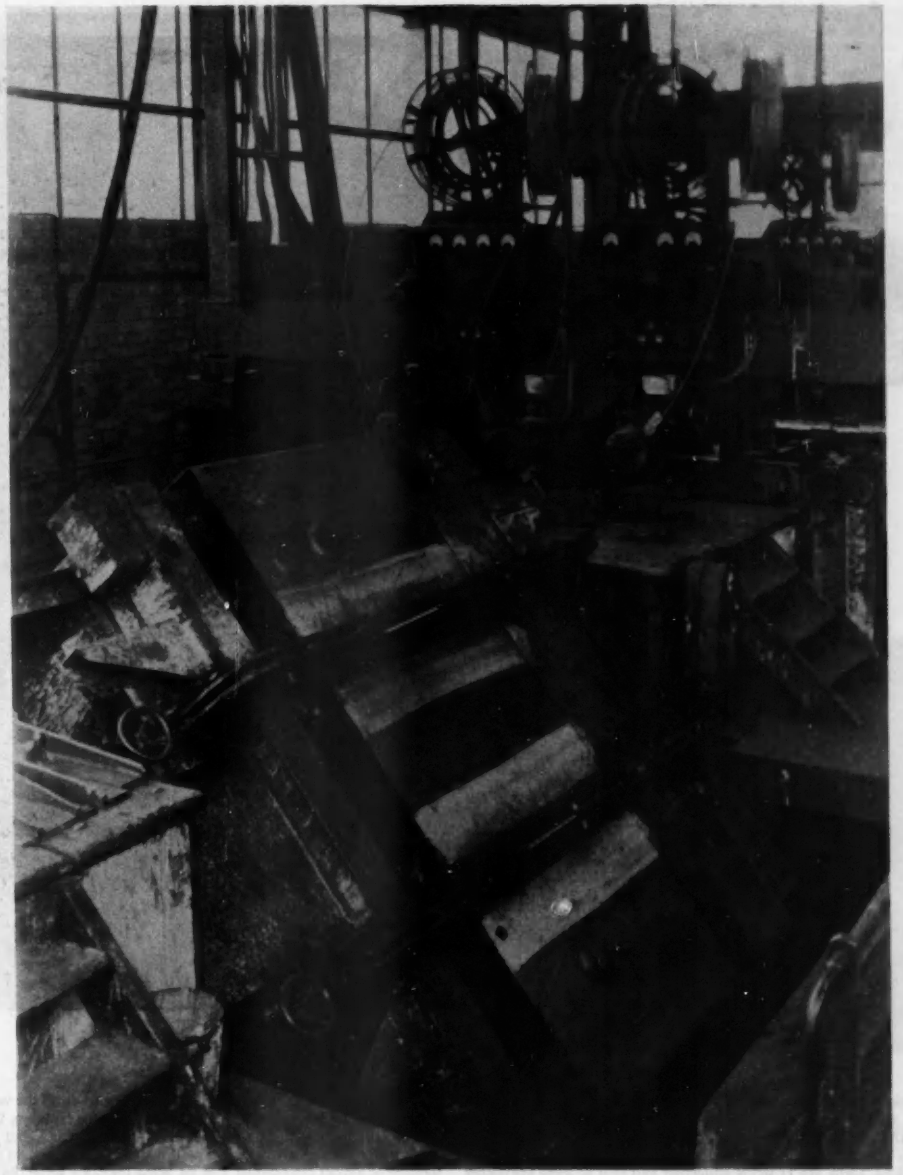


Fig. 9

component is 21 minutes in time and one operator, or for each wagon which has two ends 42 minutes and one operator.

The main advantage here is gained by getting four automatic welding heads operating in a space where it is doubtful whether two hand welders could work together comfortably.

WELDED AXLE BOX

The application of the welded wagon axle box shown in Fig. 10 is also one which at first appears doubtful as an economic proposition for automatic welding. The machine shown here is one of a group of six. The axle box shown mounted in the jig is made up of a ¼-in. pressed U-shaped section forming the bottom and sides, which is butt welded to the forged spring seat. A dust shield is formed of two pressed ¼-in. × 3/16 in. plates first welded together and then to one open end of the box. Two heavy channel guides are welded to the outside of the box throughout their whole length and an oil well top plate of ¼ in. sheet is welded along one end where it projects on the cover end of the box. Two bearing location

Fig. 10

blocks are projection welded to the inside of the box first, before the various units come on to the automatic welders. No weld on the box is longer than 11 in. and the weld lengths vary from 7 to 11 in. Four different types of jigs are required for automatic welding. There are 13 welds altogether and four of them are corner welds where, owing to the small backing in the joint, the welding current has to be kept as low as that which would be used with hand welding. The various welds are six $\frac{1}{4}$ in. fillet welds each 11 in. long, two $\frac{1}{4}$ in. vee butt welds 10 in. long, three $\frac{1}{4}$ in. corner welds $7\frac{1}{2}$ in. long and two $\frac{1}{4}$ in. corner welds 10 in. long. It should be noted that the small corner welds where the current is limited to hand welding values total 41 in., is 32 per cent. of the total welding length on the box. They are, however, small compared with the other fillet and butt welds. Consequently the proportion of total welding time where hand welding might be equal is smaller than the length of weld at first suggests.

As a hand-welding project it might be possible to do all the welding on three different jigs. This roughly reduces the handling time in the ratio of about 4 : 3 in favour of hand welding, but the automatic machines are arranged with double loading jigs, so that welding is almost continuous, one jig being reloaded while the job in the other is being welded. Although the additional loading operation exists and labour has to be provided for it, it does not affect the production time in any way.

A particular drawback to automatic welding in this and similar cases is the number of starts required, in this case 13 in a total length of $10\frac{1}{2}$ ft. of welding. A hand welder can strike an arc in less time than it takes to position an automatic head and strike the arc, and in a case like this a hand welder could decrease this striking time by about 15 to 30 secs.

The estimated hand welding time for the whole job is approxim-

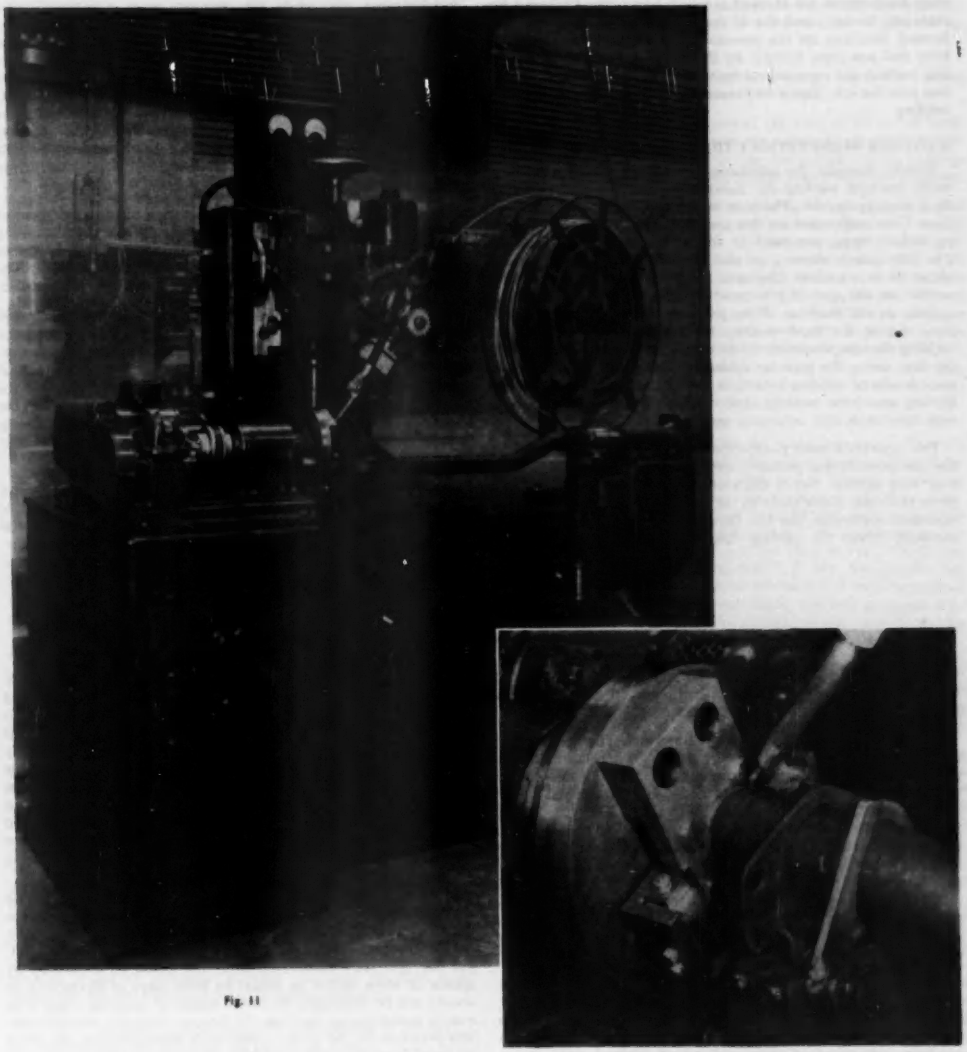


Fig. 11

ately 13 minutes. The actual automatic welding time is 5·6 minutes. If an additional half minute is allowed for each of the 13 striking times, the total automatic welding time is 5·6 + 6·5 minutes = 12·1 minutes. This comparison shows very little saving, 1 minute only with automatic, but an important point is that this is a continuous process, in which, if hand welding were adopted, the operator would be starting a fresh weld about every 80-90 seconds, and at the end of each 10 in. or 11 in. run would have to turn the jig to a fresh position and so on continuously. The fatigue on the operator would be very high and the estimated hand welding times could not be kept up. With automatic welding the fatigue on the operator is reduced considerably, as he can concentrate on changing the jig position and can almost forget about the welding operation after commencing the arc. The arc is automatically switched off at the end of each run. Another important factor in this particular case is that the whole of the six automatic machines are operated almost entirely by apprentice and semi-skilled labour, which can be adopted with automatic welding, but not with hand welding.

In considering all points, *viz.*, (*a*) the additional loading time but its not affecting the production rate; (*b*) the fatigue on the hand welder with his possible inability to maintain the saving of half a minute on striking times, or even the estimated weld times, for long periods; (*c*) the use of semi-skilled labour; (*d*) the consistent results to be obtained with automatic welding, the advantages lie with automatic welding. There is, in addition, of course, a slightly higher welding speed and the economy of using a continuous electrode.

A point worth stressing in this and the previous case is that all

plate components are blanked out on a press. The U-shaped box sides and bottom, and the U-shaped dust shield plate are press formed. Similarly on the previous example the U-shaped wagon body end was press formed. By this method, and I think only by this method, can repeated accuracy be maintained on mass production jobs like this. This is very necessary for the success of automatic welding.

ANOTHER MASS PRODUCTION JOB

Finally, consider the application in Fig. 11, which is an automatic machine welding the bumper brackets on to a motor-car front suspension tube. The inset view shows a close-up of the weld area. The components are first tack welded together on a separate jig before being presented to the automatic welding machine. The fillet size is about $\frac{1}{4}$ in. and the automatic welding speed is about 20 in. a minute. The total length of weld is $6\frac{1}{4}$ in. A hand welder on this size of job could possibly complete the weld as quickly as the machine, if the job were motor driven as shown here. Again, for hand welding the assembly jig used for tack welding the components could be developed to be also the welding jig, thus saving the time for reloading in one jig. Without going into details of welding speeds, it can be proved that the overall loading and hand welding time or floor-to-floor time is shorter with hand than with automatic welding.

This again is a mass production job. Short trials with one or a few components are probably little guide to the average results over long periods. Nor is the average hand welding speed with a given electrode much guide to the actual welding time. On highly repetitive operations like this (the welding time is only 15 to 20 seconds), where the loading time may equal or approach the welding time, and where the operator has a number of hand movements, such as the putting down and taking up of welding pliers and possibly hand shield or flap screen, and the changing of the jig, it is first of all noticed that the efficiency of the welder drops off rather sharply, as compared with a hand welder working on a long seam. The welder in this case, when he settles down, usually concentrates consciously or otherwise on one operation, such as the reloading operation and relaxes in the other, such as the welding operation. I think the choice is whichever he feels convinced gives him the highest efficiency, but a relaxing period seems necessary.

In automatic welding, except for initiating the arc, the operator pays little attention to the welding and usually waits concentrating on the time for reloading or change over. Fatigue is thus reduced and the drop off in loading times is consequently reduced. The maximum welding speed is, of course, maintained by the machine.

An important factor with automatic applications on small repetition jobs like this is to ease as far as possible the necessity for the operator to concentrate on the various operations, particularly the welding operation, and it therefore becomes essential that successive components should be identical and jig locations and clamps accurate, so that there shall be no necessity for the operator to adjust the head on successive components or during welding. To have to do so not only increases the fatigue, but also loses time in the operation.

These examples serve to show that the length of the run, the size of joint, the speed of welding and electrode economy may not be the important factors in deciding whether or not a job is a good automatic application.

DISCUSSION

The President, Mr. Howard J. Thompson, said he thought it would be agreed that Mr. Latimer had made an excellent survey and had shown great knowledge of his subject.

In his own experience, two things stood out. The first was the quality of the weld, which was of primary importance. People tended to think that automatic welding permitted so many more welds a minute and that it could be done at a colossal speed; but the first consideration should be quality. Secondly, it had been found that a qualified welder need not be employed to operate an automatic welding machine. An intelligent man, given a thorough instruction in the operation of the machine, did better than a qualified welder. With due respect to the latter, he had preconceived ideas, but with automatic welding machines instructions were supplied by the makers. Hand welders had, of course, to be employed as well, because there were many awkward jobs which could not be done automatically.

Some of the problems tackled by Mr. Latimer were fairly complicated and some were small jobs. There would, however, appear to be endless cases where automatic welding could replace hand welding. Much depended, of course, on having a long run and being able to get sufficient steel to keep it going.

Mr. R. G. Braithwaite suggested that Mr. Latimer had been too modest in comparing hand and machine welding times. He had mentioned a rate of 40 in. of hand welding in six minutes. What size of electrode was used and what current? According to his own calculations, which were very rough at the moment, he would say that six minutes was the arcing time and not the "pay" time for a welder doing an ordinary day's work.

His general experience of work of this kind showed that something like four times the output of manual welding could be expected, with a complicated set-up, from an automatic machine. On the continent, where larger-size work was done and where more automatic machines were employed, the equivalent of twelve times the amount of hand welding had been accomplished.

With regard to plate girders, he did not think it necessary for a plate to be welded up with stiffeners in position. By means of a suitable arrangement of jigs, the main welding could be put in first and the stiffeners afterwards. It was a matter of design and of a correct approach by the designer. He had spoken about this on many occasions and he did not intend to enlarge on it. It would not, however, be possible to economise in time if only 4 ft. of seam were done at a time by automatic welding with the stiffeners in. Mr. Latimer had not made this point, but perhaps it was covered in the paper, which members had not as yet had an opportunity of reading. For automatic welding, the design and lay-out of the operations must be such as to permit the maximum use of the equipment. One did not want to work to the same pattern as in the more normal hand welding process.

With regard to the allowance of half-a-minute for striking the arc, this was—he realised—a difficult problem. The machine came down; the arc did not fire; and consequently there was a little delay. The electrode stuck and the operator had to switch off, cut out, and start again. But surely this could be eliminated by means of some device or other? In these days of electronics, it should not be impossible to devise means of injecting a spark to ensure instantaneous ignition. In his own concern, the difficulty was overcome by the simple expedient of placing a little steel wool or swarf from the drilling machine immediately over the point of strike. This gave instantaneous ignition, but it was a subterfuge and not automatic welding. Had the author considered a device to inject a spark and ensure instantaneous ignition immediately the electrode struck?

At the beginning of the paper, the author said that the control of the arc was probably better than control by the operator. He had not made the point, however, that the automatic machine had not the power to direct the path of the arc to the same extent as had the welder. As he had pointed out, if there were any deviation in the arc—if the seam wandered off its position, as it well might do—the machine had to be adjusted by manual means.

The author had pointed out that exact fabrication was necessary. This should be emphasised with any welding process. Even with hand welding it was well to give very careful attention to joint fit-up and everything else.

The President said that one idea had often struck him. In looking

at an automatic weld, one saw what looked like a perfect weld, but one could not, of course, look inside to see how perfectly it was done. He always liked to compare automatic welding with gas cutting. A plate gas cut automatically, as compared with one gas cut by hand, showed a perfectly straight line, and this suggested that automatic welding was the same. With all due respect to the human element, one had a perfect mechanical line, and one was bound to get a very much better job. In hand welding with single electrodes, there was always the point where one electrode finished and another started, and this made a rather ugly blob. Nor was it good practice to weld on a weld, as one had to do with the second electrode.

Automatic welding had, he thought, a very great future. The author had not mentioned submerged arc welding, the Aircomatic process and so on. But there was no doubt that great strides had been made. A great deal of flash welding was done in industry, and many miles of pipes were made by pressing a button and flash welding. That could be called all-automatic, but the strides now being made with automatic welding in all its forms were outstanding.

Among the latest developments were the Argonarc and Aircomatic processes, which were a great step forward in the welding of aluminium and stainless steel. Some of those present might be interested in oxyacetylene, but he thought that in time the new process would supersede oxyacetylene welding for straight runs, because it made a perfect job. He had seen it in operation some two years previously at a research laboratory in New Jersey. The joint was perfect, appeared like a soldered job and was one of the most beautiful welds he had ever seen. He felt quite sure that this process would be employed in the future. Unfortunately, the cost was high. In America the cheaper helium gas was available in place of argon gas. However, a very much better job could be done in welding stainless steel and aluminium. Over there he had seen the welding of some terrible mixtures of high tensile steels about 1½ in. thick, as well as the welding of copper and different alloys. It was of tremendous advantage in the latter cases.

One would not use the process, of course, for normal mild steel welding, as it was too costly. At present there was no competitive process for the automatic welding of, say, gauges from 14 up to ¼ in., of a type similar to the fusion arc. In America, he had seen as low as 14-gauge mild steels being welded by the submerged arc process. As members were aware, however, this put a big bead on the weld which had, in many cases, to be cleaned off. There seemed to be some scope for a competitive process for the welding of mild steel.

One great advantage of the Argonarc automatic welding process was the very smooth weld. In many articles, it was necessary to grind off the weld afterwards to make a perfectly smooth finish and polishing might also be necessary. It cost three times as much to grind off as to weld, so that although welding might cost more, there would be a saving on the grinding. Grinding was a terrible job in any case, and it was hard on the men; moreover, it was difficult to get an automatic grinder. The hand operator might easily dig into the plate and make irregular recesses.

Dr. W. I. Pumphrey asked whether it was because of mechanical or metallurgical troubles that the automatic welding device could not be used for positional welding.

Mr. H. Martin congratulated Mr. Latimer on taking the war into the enemy camp and quoting examples which obviously favoured hand welding. With short runs on complicated jobs where the current had to be limited because of the position of the weld or the thickness of the material, the exponent of hand welding could make out a very good case for the opposite argument. Better jigging and perhaps a belt conveyor, might enable these short-run jobs to be done competitively by hand welding.

He had been very interested in the diagrams of circuits, and in this connexion he would like to have Mr. Latimer's advice on the clutch linings used on the bevel edge clutches. If a lining were not used, was there a tendency to develop flats due to spinning on the larger wheel?

He would also like to know what were the respective merits of alternating current and direct current in automatic welding and whether the elimination of arc blow by the use of alternating current was worth while.

Mr. Latimer, in reply, said that he must apologise for rushing over many points in his summary of the paper.

Mr. Braithwaite had asked about the rate of 40 in. of hand welding in six minutes. This was the actual arcing time. It was done on a quarter-inch fillet in the horizontal/vertical position and the figure was supplied by the people who bought the machine.

It was possible with automatic welding to get up to ten and twelve times the speed of manual welding. This was usually achieved, by the ability of the machine to travel accurately at high speeds, on heavy plate by very high currents and on very small welds, where it was impossible for a hand welder to control at high speeds, especially if he had to move himself along the joint instead of the joint moving under him. This wide difference between manual and automatic welding occurred with both thin gauge plate and heavy plate, and on this point he agreed with Mr. Braithwaite. The purpose of showing these examples, however, was not particularly to demonstrate the high speeds achieved but to bring out some of the other points of advantage in automatic welding.

With regard to the plate girder, he could only speak from his own experience. Numerous applications had been considered for plate girder welding, but in no case had it proved possible to persuade the user to leave out the transverse stiffeners. Even proposals to tilt the flanges back or to try to hold them in a jig had met with no success. The usual excuse was, "We shall never get the transverse stiffeners in if we do not put them in first. The flanges will buckle and make it impossible." If Mr. Braithwaite had developed a process and had found that he could weld throughout the whole length on flange to web fillets, it would be useful if he would notify all the other manufacturers in the country, as this would ease the position for automatic welding considerably!

This example was intended to show that even where automatic welding might appear ideal, with a plate girder the increased speed of welding automatically might be offset by delays in manipulating the head many times and filling in the corners with hand welding.

As to the half-minute quicker start with hand welding, the example shown where this was allowed was the welding of an axle box. It often happened that an operator standing on one side of the job could do better and more consistent welds by bringing the machine back to the same starting-point. These machines would run from one end of the job to the other and then reverse and run back. In practice it was found that about 60 per cent of users failed to take advantage of this. They returned to one starting point for each run and ran in the same direction. This took longer and added to the time taken in setting the head and striking the arc. Furthermore, positioning the head exactly where one wanted to start with the automatic machine, it usually took some seconds for the electrode to contact the plate. The arc was struck, the electrode reversed, and the arc was established at its correct length. When it was established, and only then, its travel commenced. A hand welder with a pair of pliers hung on a hook with an electrode loaded could strike an arc and commence travel more quickly. He had probably been lavish in allowing half-a-minute in this particular case. In the case of the wagon body, where he had not gone into details, it could easily be shown that the arc striking by manual welding could commence more quickly, but whether the operators could maintain it consistently, he did not know and doubted.

He had tried to emphasise the fact that the hand welder could easily direct the arc. He moved the position of the electrode and sometimes played on one plate more than the other when travelling along a seam. This could not be done so easily with automatic welding. The head could not be manipulated or the speed of travel altered so quickly on an automatic machine, and as it was also undesirable to do either, it became a necessity to make very much more carefully prepared joints for automatic welding.

In reply to the President, he said that although the weld might be more perfect with an automatic machine, it was still necessary to set the job carefully to obtain the best results, and that might

involve a few trials before the desired result was obtained. Once the job was set, however, it could be maintained accurately over long periods. In fact, it could be set continuously, and that was the main advantage. The hand welder could, he presumed, produce equal results under given conditions, but consistency counted in such a case.

A question had been asked about the clutch linings on the cone-shaped clutches. These particular clutches were case-hardened steel; and although the contacting pressure was of the order of 40 to 50 lb., there was, over a fairly long period of two or three years, no sign of flats. Clutches of this kind had been used for longer periods. People in the motor car industry were continually using them, day in and day out, and it was found necessary to renew them every two or three years.

He did not think he could say a great deal about the relative merits of alternating and direct current. It depended almost entirely on the design of the electrode. As regards the quality of weld produced, if a designer designed an electrode and found it more suitable for direct current, he would probably advocate that. On the other hand, another designer might go out purposely to produce electrodes suitable for alternating current.

As regards arc blow, particularly on circular welds, it was definitely better to use alternating current. On longitudinal joints, except for the actual ends of the weld, arc blow was not particularly troublesome. In corner butt welds, direct current could be the downfall of the job, and even with magnetic compensating blocks on either side of the weld it was pretty troublesome to get rid of the arc blow. Here again, the automatic electrode had to be positioned in a downhand position, whereas the hand welder could get round these troubles more easily by angling his electrode a degree over one side or the other or varying it as he went along.

In comparing hand welding with automatic welding he had probably, he thought, been generous to hand welding speeds with the idea of bringing out certain points for consideration. On most applications, if automatic welding could not be shown to produce increased speed, it was condemned. Personally, he would rate highest the fatigue of the operator. Any saving here was an economy, though speed of welding was undoubtedly a further advantage. Among other considerations were the number of welding heads that could be put in a given space (for instance, on the wagon body), as compared with the number of hand welders, and also the consistent production rate.

As to the positioning of a welding head, he had not followed the question entirely.

Dr. Pumphrey said that what he wanted to know was whether there were any reasons why automatic welding should not be used for vertical welding. Must it always be used in the downward position?

Mr. Latimer said that up to the present no electrode had been made for welding in a vertical or overhead position. Again, machine difficulties were numerous, and it would probably be ruled out on account of high initial costs. A vertical weld would have to be of reasonable length to enable a machine or rack of some kind to be hung up and allow the welding head to be propelled in a vertical direction. To guide the head the operator would have to go up and down with it except on a short run, and a short run would not be an economical proposition. The question whether automatic welding could be carried out in a straight run with a close controlled arc or whether it was necessary, as in hand welding procedure, to draw the arc out slightly or oscillate it vertically while welding, remains unanswered. The same consideration applied to the overhead position. It was the doubt on this point and the lack of investigation that had prevented machines and electrodes being developed.

Mr. C. C. Bates asked the author whether, in his opinion, the shape of the weld bead and the longitudinal appearance of the weld were any indication of the homogeneity of the weld, as he had found cases in which a smooth even bead from an automatic covered electrode weld had indicated worm porosity.

Secondly, he asked whether the author favoured a fixed backing bar or a moving slipper back-up for automatic welding of thin plate material.

Finally, he asked the author what developments were taking place in this country with respect to semi-automatic welding equipment with which welds could be done manually in the vertical and overhead positions. He believed, speaking from memory, that existing continuous electrodes, according to B.E.A.M.A. classification, could be used in more than the downhand position.

Mr. Latimer said that the shape of the bead and the undulations on the top of the weld longitudinally in metallic arc welding gave very little indication as to the homogeneity of the weld. The appearance of the metal belied it. In some of the quieter welding processes such as the atomic hydrogen process, for example, a good deal of information could be obtained from the appearance of the surface of the weld.

With regard to backing bars, there were a number of arrangements which were quite suitable. The slipper type, which travelled along underneath the arc, ensured the same contact along the whole of the seam. Its usual disadvantage was, that being continuously under the arc, it needed water-cooling—which was often a problem.

Copper was mainly used under metallic arc welding, although ordinary mild steel could be employed. Copper in a single bar would never contact the full length of the joint. To do so needed tremendous clamping pressure to bring the job down on to it.

A better arrangement was to use a series of copper segments spring-loaded or pneumatically loaded underneath the job. Segments of the order of 4 to 6 in. long would be quite useful and effective, and they were as good as the sliding slipper in contacting the underside of the joint.

Semi-automatic equipments were made in 1934 or 1935 by the concern with which he was associated. They used a light-coated electrode. They were marketed for a while but found very little use. The difficulty with the semi-automatic type of electrode for fusion arc welding of steel was the limit to the size of rod that could be used. It had to be put through a hose or flexible conduit of some kind, feeding it into a hand tool which the operator moved along the joint. The curvature of the hose added considerably to the friction of feeding the electrode. In addition, there might be—and usually was—additional friction of the contact brushes in the hand tool and a fairly high-powered motor was needed, which again added inertia to the whole control system. To get a close control arc with an eight-gauge fluxed electrode was extremely difficult, because of speed of feed, handling variations and heavy friction drag on the electrode.

Some semi-automatic systems used very small gauge wire, of the order of 1/16th or 1/8th in. diameter, which was much easier to feed and control, but with these electrodes much current had to be pumped in to equal the deposit of a six-gauge or four-gauge hand-welding rod. Progress was nevertheless being made by various companies now with semi-automatic machines. There appeared to be a fairly big demand for semi-automatic equipment in many applications, especially inside large constructions, where it was often impossible to get an automatic machine down to the job.

One particular case that came to mind was that of the wagon, the ends of which he had shown. The whole of the inside welding could have been done by a semi-automatic tool.

Mr. Bates said that one application that had come to his notice was a circular storage tank with a continuous circumferential weld. That would be ideal for semi-automatic welding.

Mr. Latimer said that a platform would be needed to house the driving mechanism. The welder could be away from it but in a tank of that size one could not expect the run from the driving mechanism to the hand tool to be longer than 12 or 14 ft. Anything greater became quite a big problem in drive mechanism.

Mr. H. O. Willrich said that he understood that submerged arc and Aircomatic equipment was now being made without complicated controls, electronic or otherwise. A constant wire

feed was being tried out, on the assumption that each diameter of wire had a characteristic burn-off rate which, when combined with a suitable drooping characteristic of the current supply unit, made it possible to keep a constant arc length, thus doing away with intricate automatic controls. Was there any possibility of achieving this with straight metallic arc welding?

Mr. Latimer said that some of the standard automatic equipments—he had particularly in mind the clutch drive mechanism—were free to operate as self-regulating systems. The motor was set at a constant speed and the arc voltage relay, if it was contacting the top contact (that was to say, the feed down contact on the relay), was feeding forward at a constant speed. The condition of self-regulation was not peculiar to the Aircomatic process. The arc characteristic might be of a lower value, but it intersected the drooping characteristics of the welding generator at an angle very similar in character to the standard metallic arc. The standard metallic arc could therefore be self-regulating.

The success of the Aircomatic process depended on two main factors: (1) One was the high speed of feed, which was somewhere between 100 and 700 in. a minute feed down of the electrode. The intensity of current allowed this to be achieved. The time for correcting a variation in arc length was therefore relatively small with these high speeds. With the metallic arc welding process using a fluxed electrode the feed down speeds were of the order of 10 to 40 in. a minute and the time for changing a given arc length was relatively longer, so much so, that the arc could extinguish during that period.

(2) Again, with the aluminium rod in the Aircomatic process, the voltage variation for a given arc length change was relatively small compared with metallic arc. For instance, with the average current used with the Aircomatic process—between 200 and 290 amps.—to increase the arc length from 0·2 to 0·3 in. required an increase in arc voltage of less than 2 volts. With metallic arc, on the other hand, a change in arc voltage of the order of 6 volts would occur. In the Aircomatic process, if the arc were lengthening slightly—which it could do under the operator's manipulation—there was very little change in the arc current or voltage. Consequently, the arc was not disturbed by small variations in length. With the metallic arc, small variations in length caused considerably more disturbance. For instance, at 6 volts the amount of current and the burn-off rate would alter considerably. A further factor was the size of droplet coming off the end of the aluminium rod in the Aircomatic process. It was, he thought, relatively small compared with the metallic arc rod.

Mr. Willrich pointed out that it was spray with the Aircomatic process.

Mr. Latimer said that the size of the droplet could disturb the whole of the arc stability, but there was still no reason why the metallic arc should not be self-regulating. It was the two factors—high speed and relatively small disturbance in the arc for arc length changes—which made the Aircomatic process self-regulating.

Mr. Willrich said that the feed down speeds in the submerged arc process were more or less similar to that of Aircomatic.

Mr. Latimer agreed, but pointed out that in the submerged arc process there was still the problem of arc voltage change with length, although the feed speed was considerably greater than in the open arc process.

Mr. Willrich said that in the submerged arc process there was the same phenomenon as in the Aircomatic process with the droplets coming over in spray and not in globules.

Mr. Latimer said that he had not seen any confirmation of this. It might be the case, but there was no proof of it as far as he knew.

Mr. R. G. Braithwaite, who moved a vote of thanks to the author, said that the Institute was very fortunate in having a paper of this category for inclusion in its records. Very little published information was available on up-to-date modern automatic plant. He wondered what was wrong with the industry in that it had not created some demand for what must be a very necessary tool in manufacturing processes. Some fifteen or sixteen years ago, when the Institute was developing, the question of research had been taken up with the authorities. Committees were instituted for spot and resistance and butt and flash welding and a lot of people asked very vigorously what was going to be done about automatic metallic arc welding. They were told that there was no demand, and this was virtually the position not only in this country but also in America and on the continent. There was no upsurge of demand from manufacturers for this tool. They simply accepted what was produced. Nobody had demanded automatic arc welding, which was more flexible than the machines at present in use.

While the Institute was fortunate, as he had said, in having the paper, he must commiserate with the author because he had chosen this year to present it, a year when competition for the Sir William Larke Medal was very keen. This was the first year for a long time when there had been so many first-class papers and assessors must have found it very difficult to make a selection.

The President, in associating himself with Mr. Braithwaite's remarks, said that the Institute was very glad to welcome Mr. Latimer as the runner-up for the Medal and thanked him for his paper and the interesting discussion it had provoked. It was obvious that he was a past master in his subject.

BOOK REVIEW

American Welding Society: *Safe Practices for Welding and Cutting Containers that have held Combustibles*. Pp. 12, illus, 8vo, 50 cents. (1951.)

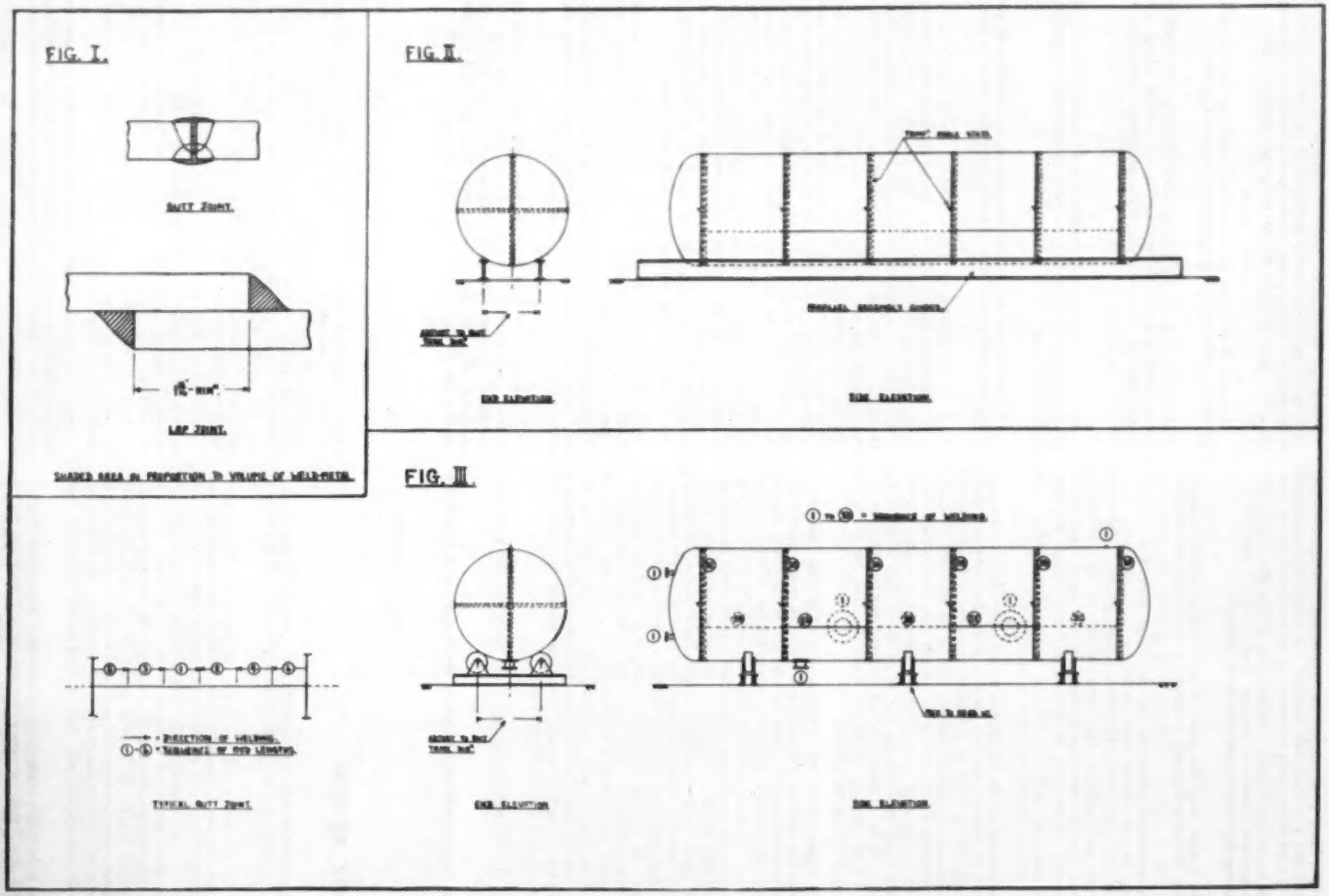
Whilst the leading oil and petrol companies of Great Britain recognise the precautions that must be taken, the dangers that are attendant when repairs by means of welding and gas cutting are carried out on vessels which have contained combustibles are unfortunately not so well recognised as one would expect. Probably more unfortunate is the lack of knowledge of the safety precautions that should be taken before such repairs are allowed. Consequently this revision of a standard first published in 1940 is worthy of study by the users and manufacturers of such containers, and particularly by individual welders who may be called upon to execute such work.

The information concerning the necessary precautions is given in such detail that the veriest layman, by following the recommendations given, should be able to render a vessel that has contained combustibles quite safe and in a satisfactory condition for repair by means of welding or flame cutting. Both the hot chemical and steam cleaning methods are described, whilst the actual precautions to take while the welding or cutting is being carried out, such as filling the container with water or an inert gas, are likewise fully described. Both of these cleaning methods and similar precautions are carried out by the leading manufacturers of this country.

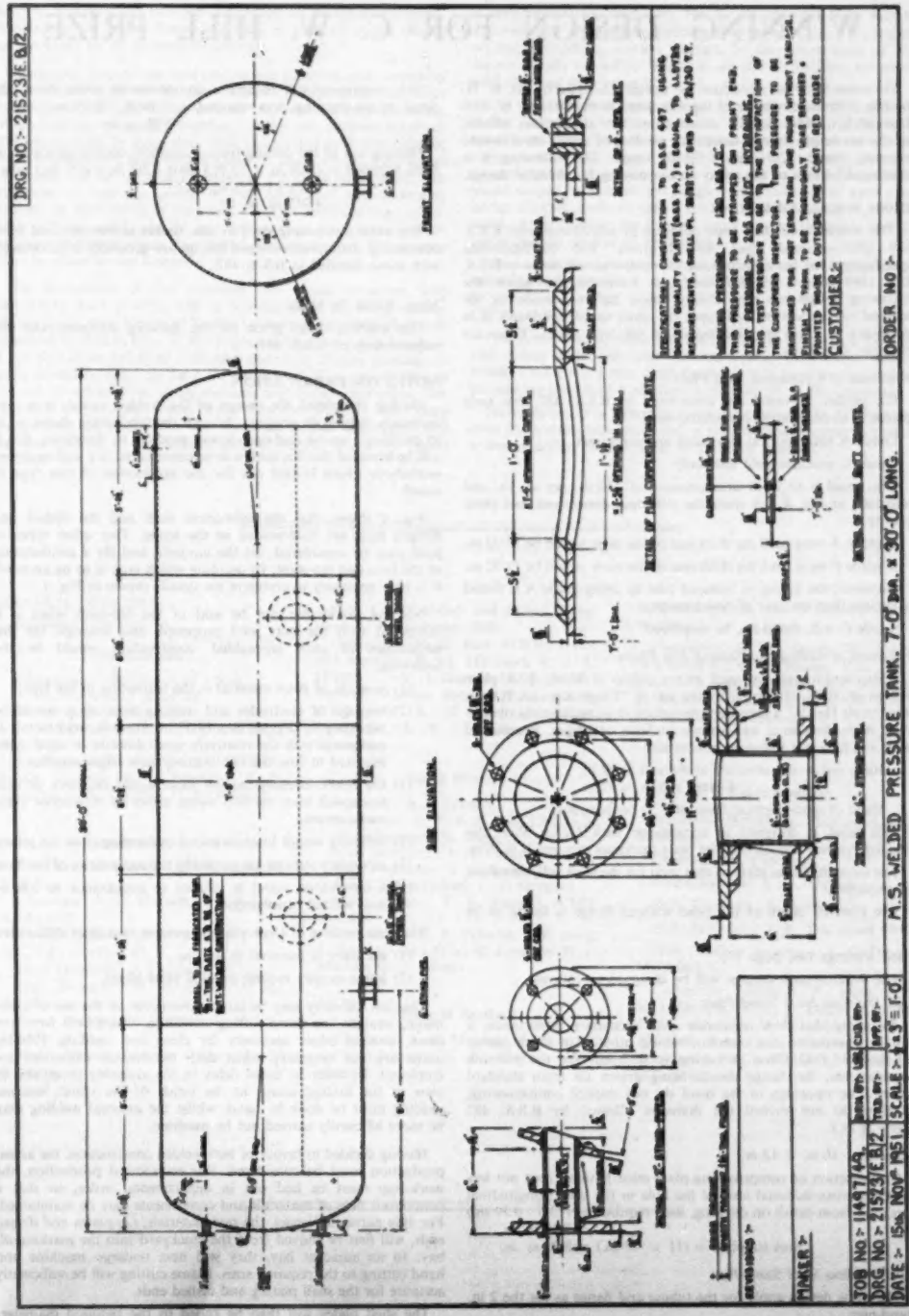
An appendix describes in detail suitable apparatus for use in the gas testing operation, to make sure that the container has been completely purged. Although the Larner Gas Sampler Apparatus so described may be quite effective, it is considered that the electrical type explosimeters that are in use in this country would be more efficient when testing vessels for gas after they have contained such fuels as petrol.

There is no doubt a definite need for information on how to execute repairs on vessels or containers that have been contaminated by carrying combustibles and this standard will undoubtedly help towards achieving the desirable end.

F. J.



C. W. Hill Prize Design, 1951


DRG. NO :- 21523/E.B/2.
A.S. WELDED PRESSURE TANK, 7'-0" DIA. x 30'-0" LONG.
ORDER NO :-
CUSTOMER :-
DRG NO :- 21523/E.B/2.
DATE :- 15th NOV. 1951. SCALE :- 1/2" = 1'-0"
TINKER :-

WINNING DESIGN FOR C. W. HILL PRIZE

On pages 86-87 we reproduce the design submitted by Mr. W. H. Stubbs, Graduate, winner of the first prize in the 1951 C. W. Hill Competition. Mr. Stubbs chose from the alternatives offered by the examiners "the re-design for welding of a mild steel riveted pressure vessel, 7 ft. dia. × 30 ft. long." The following is a shortened version of the paper accompanying Mr. Stubbs' design.

DESIGN CALCULATIONS

The riveted vessel had been designed in accordance with B.S.S. 429 : 1931—*Riveted Steel Air Receivers*. The corresponding specification for the construction of welded air receivers is B.S.S. 487 : 1949—*Fusion Welded Steel Air Receivers*,' on which the following design has been chiefly based. Before considering the method of fabrication and types of joints to be employed, it is necessary to know the thicknesses of the tank plates. These are obtained as follows:

Thickness of Cylindrical Shell Plate

Six grades of vessel are considered in B.S.S. 487, but only grades A and C will be considered here.

Grade A specifies heat treatment and weld tests.

Grade C specifies weld tests only.

The vessel is to work at a pressure of 130 lb. per sq. in. and reference to Fig. 4 will show the principal dimensions and plate quality.

If grade A were used the thickness of the plate would be 17/32 in.

If grade C were used the thickness of the plate would be 19/32 in.

However, the saving in material cost by using grade A is found to be less than the cost of heat treatment.

Grade C will, therefore, be employed.

Thickness of Dished and Flanged End Plates

If diepressed ends are used with a radius of 72 in., ½ in. plate will be required. However, by the use of "Large Knuckle Radius Rotarprest Heads" a considerable reduction in thickness is obtainable. According to a well-known maker's catalogue, a standard head will have the following properties:—

Inner radius of curvature of the end = 72 in.
Corner radius = 12 in.

Head of semi-elliptical form of 2 : 1 proportions.

This head is designed in accordance with *Lloyds Rules for Welded Pressure Vessels* and the plate thickness required is 9/16 in.

The same thickness plate as that used for the shell will, therefore, be employed.

The external depth of the head without flange is found to be 20·56 in.

Tank Fittings (see page 87)

The various tank fittings will be designed as follows:

2 in. Weldless Steel Stand-Pipes

Assuming that flow resistance is of secondary importance, it will be cheaper to use standard tubing other than taper pieces. B.S.S. 806 : 1942 Class A tubing is sufficient for the pressure requirements, the flange details being drawn up from standard tables. The openings in the head do not require compensating, as they do not exceed the diameter allowed by B.S.S. 487 ($2\frac{1}{4}t+2\frac{1}{4}$ in.).

Manholes: 16 in. × 12 in.

Cross-section of compensating plate must have an area not less than the cross-sectional area of the hole in the shell (longitudinal axis), *i.e.* from detail on drawing, area required = (13·5 × 0·59 in.)
= 7·96 *sq. in.*

Area supplied = (11 × ·75 in.) = 8·25 *sq. in.*

6 in. Weldless Steel Stand-Pipe

The same details apply for the tubing and flange as for the 2 in. stand-pipe.

This connexion will require a compensating plate. From the detail on the drawing, area required = (6·69 in. × 0·59 in.)
= 3·95 *sq. in.*

Making use of the cutting from a manhole compensating plate,
Area supplied = (5·06 in. × ·75 in.) plate + 2(2 in. × 9/32 in.) tube
= (3·79 + 1·125) sq. in.
= 4·915 *sq. in.*

The welds connecting the ¼ in. dia. socket to the shell and those connecting the aforementioned fittings are generally in accordance with those detailed in B.S.S. 487.

Main Welds In Shell

The welding detail given on the drawing complies with the requirements of B.S.S. 487.

NOTES ON FABRICATION

Having completed the design of the welded vessel, it is now necessary to plan its progress through the fabrication shops, so as to produce a sound and economical product. In describing this, it will be assumed that the tank is to be constructed in a well-equipped workshop, which is laid out for the production of this type of vessel.

Fig. 4 shows that the cylindrical shell and the dished and flanged ends are butt-welded at the joints. Two other types of joint may be considered: (*a*) the lap-joint and (*b*) a combination of the butt and lap-joint. In deciding which type is to be adopted, it is only necessary to compare the details shown in Fig. 1.

Nothing favourable can be said of the lap-joint when it is compared with the butt joint proposed, and amongst the disadvantages of such lap-welded construction would be the following:

(1) wastage of plate material in the formation of the laps;

(2) wastage of electrodes and welding time, as it would be necessary to deposit two 19/32 in. fillets in weld metal, as compared with the relatively small amount of weld metal required to fuse the two butting plate edges together;

(3) the fillets forming the lap joint would be more difficult to deposit than the butt welds, either by manual or automatic means;

(4) difficulty would be experienced in forming close lap joints;

(5) secondary stresses are caused by the eccentricity of the laps;

(6) a lap-jointed vessel is inferior in appearance to one of butt welded construction.

The butt welding of thick plating presents two chief difficulties

(1) accuracy is required in set-up;

(2) joints usually require profiled plate edges.

The first difficulty may be largely overcome by the use of automatic, straight-line flame-cutting machines, which will form the clean, straight edges necessary for close butt welding. Profiled joints are not necessary when deep penetration electrodes are employed. In order to avoid delay in the assembly shop, and in view of the limited access to the inside of the vessel, internal welding must be done by hand, whilst the external welding may be more efficiently carried out by machine.

Having decided in favour of butt-welded construction, the actual production must be considered. For economical production, the workshop must be laid out in departmental order, so that a continuous flow of materials and components may be maintained. For this particular vessel, the raw materials, *i.e.* plates and dished ends, will first be moved from the stockyard into the marking-off bay. In an adjacent bay, they will next undergo machine and hand cutting to the required sizes. Flame cutting will be sufficiently accurate for the shell plating and dished ends.

The shell plates will then be rolled to the required diameter,

and the butting edges clamped in position to maintain circularity. Meanwhile, the branch flanges and the ¾ in. dia. hyd. socket should be machined to the finished dimensions.

Eventually the various components will converge in an assembly bay. Angle stays, which have been forwarded with the other components, will help to maintain the circularity of the shell-plates, which will then be brought together, one by one, between longitudinal guides (Fig. 2). Each shell plate should first have been checked for circularity and tack welded along its seam. (*Note:* light gauge electrodes should be used for tacking, the tacks being small, but sufficient to hold the plates in true alignment, and preferably located on the outside of the vessel.) A light hand-operated screw-jack will be useful, should any adjustments be necessary when aligning the plate edges. The dished ends and other fittings may then be added to the assembly.

On completion of the assembly, the vessel, complete with temporary internal stays, will be transferred to the hand-welding department. Here the vessel should be mounted on suitable hand-operated trunnions (Fig. 3), the joints examined and wire-brushed. Care should be taken to minimise distortion during welding. A plug should be fitted to the ¾ in. dia. socket. The various fittings should be welded first, using medium penetration electrodes. The internal longitudinal seams may then be welded with deep penetration electrodes. The last operation in this department will be the welding of the internal circumferential seams by means of deep penetration electrodes. Finally, the external tacks may be removed, and the external joints wire-brushed. (*Note:* During all welding operations, sudden changes in the temperature of the vessel—usually caused by draughts—should be avoided, otherwise weld cracking may occur.)

The tank, still with internal stays in position, will then pass on to the automatic welding machine. This machine, of the submerged arc type, should be capable of longitudinal movement, whilst motor-driven rollers under the vessel will facilitate controlled circumferential movement. Once more the external longitudinal seams should be welded first (single pass), the ends of each seam being chipped flush to allow for the following circumferential welds. After cooling, the internal stays may be removed, and the vessel cleaned up free of weld spatter.

The socket threads may be checked prior to testing, painting, stamping and despatch.

CONCLUSION

It is interesting to note that the calculated weights of the shell and dished ends only are: Riveted vessel, 159½ cwts., welded vessel, 151½ cwts. From these figures it will be seen that welded fabrication has saved 5 per cent. in the weight of plate material.

Nevertheless, it is somewhat surprising that B.S.S. 487 requires, even for a stress-relieved vessel, a shell thickness equal to that of a closely drilled riveted vessel of the same capacity.

BRANCH OFFICERS—

continued from page 70.

Southampton

Chairman: J. Boylan, A.M.I.N.A.
Vice-Chairman: J. Brogden.
Hon. Treasurer: G. Giles.
Hon. Secretary: J. H. Gillespie, B.Eng., M.I.N.A., A.M.I.C.E.
Committee: W. F. Bundy, J. Hillier, R. G. Osborne, R. L. Paterson, R. F. Rothery, E. R. Thomas, H. A. Watton.

South London

President: Sir Charles Lillicrap, K.C.B., M.B.E.
Chairman: J. L. Hamilton, A.R.T.C., A.M.I.E.E.
Vice-Chairman: A. J. Elliott, B.Sc., A.C.G.I., A.M.I.C.E.
Hon. Treasurer: J. Lancaster, B.Eng.
Hon. Secretary: H. E. Dixon, M.Sc., A.I.M.
Hon. Programme Secretary: W. L. Hinton.
Hon. Appeals Liaison Officer: L. L. Arundel.
Hon. Correspondent and Dinner Secretary: A. J. Hipperson, B.Sc.
Committee: R. G. Burt, O.B.E., B.Sc., M.I.Mech.E., R. G. Harrison, P. J. E. Heath, L. A. Lidstone, M.S.E.(Mech.) (rep. of Medway Section), E. J. Marsh, B.E.M., W. K. B. Marshall, B.Eng. (*ex-officio*), A. V. I. Molleson, A.M.I. Chem.E.

South Western

President: A. J. Francis.
Chairman: A. W. Wall, A.M.I.Struct.E.
Vice-Chairman: L. Hays.
Hon. Secretary: J. H. Payne.
Hon. Treasurer: A. Gilliard.
Hon. Correspondent: C. F. Gregory.
Hon. Auditor: F. K. Fennell, A.M.I. Struct.E.
Committee: E. R. Fellows, I. B. Ford, J. Hathway (*ex officio*), E. Jones, W. H. Y. Masters, K. I. Palmer.

West of Scotland

Chairman: F. P. Macrae, M.I.Struct.E.
Vice-Chairman: J. E. Jones, A.M.I. Mech.E.
Hon. Secretary and Treasurer: Robert Walker.
Committee: R. E. Doré, W. Heigh, M.I.Struct.E., C. J. Jensen, B.Sc., M.I.E.S., D. M. Kerr, A.M.I.M., J. E. McInnes, T. McIvor, Dr. J. Orr, B.Sc., M.I.Mech.E., M.I.E.S. (*ex-officio*).

Wolverhampton

President: Howard J. Thompson, M.I. Mech.E.
Chairman: E. Flintham.
Vice-Chairman: C. A. Hadley.
Hon. Treasurer: S. H. Griffiths, A.I.M.
Hon. Secretary: J. R. Thomas.
Hon. Publicity Secretary: L. C. Dipper, M.I.Mech.E.
Committee: Major R. W. Allan, R.E., F. J. Daniels, B.Sc., L. Dann, F.I.F.M., J. H. Gilmore, M. R. Liddiatt, E. J. Mitchell, B.Sc., S. K. Stokes, J. H. N. Thompson, M.C., M.A., A.M.I.Mech.E. (*ex-officio*).

Latest Additions to the Library

As a supplement to the Library catalogue, this section of the *Transactions* contains particulars of books and pamphlets added to the Library during the second quarter of 1952. The books, pamphlets and periodicals specified are available on loan to members of the Institute.

Publications preceded by an asterisk are donations to the Library from authors or publishers; those preceded by a dagger are donated by the James F. Lincoln Arc Welding Foundation.

BOOKS AND PAMPHLETS

***ALUMINIUM DEVELOPMENT ASSOCIATION**
(a) The heat-treatment and annealing of aluminium and its alloys. Illus. 1951. (*Information Bulletin No. 3.*) **(b) Proceedings at a Symposium on welding and riveting larger aluminium structures.** Illus. 1952. (The papers on welding comprise: "Recent researches on the arc welding of thick aluminium plate," by P. T. Houldcroft, W. G. Hull and H. G. Taylor; "Practical aspects of the argon-arc welding of aluminium alloys," by J. R. Handforth.) Publishers: Aluminium Development Association, 33, Grosvenor Street, London, W.1. Price: (a) 2s.; (b) 4s.

***BRITISH CONSTRUCTIONAL STEELWORK ASSOCIATION**
The application of the plastic theory to the design of mild steel beams and rigid frames, by F. A. Partridge. Examples of structural steel design to conform with the requirements of B.S. 449 : 1948. (*B.S.C.A. Publications Nos. 3 and 4.*) 1951. Publishers: British Constructional Steelwork Association, York Mansion, 94-98, Petty France, London, S.W.1.

***BRITISH ELECTRICAL AND ALLIED MANUFACTURERS' ASSOCIATION (INC.)**
Forty-first annual report, 1951-52. Publishers: B.E.A.M.A., 36, Kingsway, London, W.C.2.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION
Annual report of Council, 1951. Publishers: British Iron and Steel Research Association, 11, Park Lane, London, W.1.

BRITISH STANDARDS INSTITUTION
(a) 639 : 1952.—Covered electrodes for the metal-arc welding of mild steel (12 s.w.g. (3/32 in.) and larger, for hand operation). (b) 1845 : 1952.—Filler alloys for brazing (silver solders and brazing solders). (c) 1856 : 1952.—General requirements for the metal-arc welding of mild steel. Publishers: British Standards Institution, 24, Victoria Street, London, S.W.1. Price: (a) 4s.; (b) 2s.; (c) 5s.

***B.T.H. ACTIVITIES**
Published bi-monthly by the British Thomson-Houston Co. Ltd. Vol. 23, no. 1, 1952, *to date.*

***CITOGÈNE**
Revue technique editeé sous les auspices du "Comité de Recherches de la Holding Intercito." Vol. 1, no. 1, 1952, *to date.* (This periodical contains papers on welding applications carried out by means of electrodes manufactured by Oerlikon.) Publishers: "Citogène," 4, Chemin de Valfaye, Lausanne, Switzerland.

***COPPER DEVELOPMENT ASSOCIATION**
C.D.A. No. 23.—Copper in chemical plant. C.D.A. 25.—Copper pipe-line services in buildings. C.D.A. 38—Copper alloy resistance materials. C.D.A. 42.—Copper flashings and weatherings. C.D.A. 43.—Copper and its alloys in engineering and technology. C.D.A. 47.—The welding, brazing and soldering of copper and its alloys. Publishers: Copper Development Association, Kendals Hall, Radlett, Herts. Supplied free of charge to those giving evidence of responsible status or genuine interest.

***UCHS, E., and BRADLEY, H. (Editors.)**
Welding Practice. Vol. III.—Welding of non-ferrous metals. Illus. 1952. (This volume has been written by past and present members of the Welding Panel of Imperial Chemical Industries Ltd. Vol. III deals with the metallurgical characteristics of non-ferrous metals, together with welding procedures by various processes. A section is devoted to the brazing of ferrous and non-ferrous metals.) Publishers: Butterworths Scientific Publications, Bell Yard, Temple Bar, London, W.C.2. Price: 22s. 6d.

G.B.—MINISTRY OF LABOUR.—FACTORY DEPARTMENT
Memorandum on electric arc welding. 5th ed. revised, 1951. (Form 329.) Publishers: H.M.S.O., York House, Kingsway, London, W.C.2. Price: 9d.

***INTERNATIONAL NICKEL CO. INC.**
Fabrication of Monel tanks for boats: water, gasoline, fuel oil: recommendations and suggestions on metal thickness, joint type and welding process. Illus. 17 pp. (1952.) Publishers: International Nickel Co. Inc., 67, Wall Street, New York, 5. Available at the Mond Nickel Co. Ltd., Sunderland House, Curzon Street, London, W.1.

KLOSSE, E.
Schweisstechnische Berechnungen. Illus. 1951. (*Werkstattbücher, Heft 102.*) Publishers: Springer-Verlag, Berlin. For sale at Lange, Maxwell & Springer Ltd., 41-49, Neal Street, London, W.C.2. Price: 6s. 4d.

†J. F. LINCOLN
Incentive management: a new approach to human relationships in industry and business. 1951. Publishers: The Lincoln Electric Co., Cleveland 17, Ohio. Price: 1 dollar 50 cents.

LLOYD'S REGISTER OF SHIPPING
Rules and regulations for the construction and classification of steel ships. Illus. 1952. Publishers: Lloyd's Register of Shipping, 71, Fenchurch Street, London, E.C.3. Price: 42s.

†SAXE, VAN RENSSELAER P.
Manual of structural welding practice: Saxe system welded connection units for welded assembly. Illus. 4th ed. 1951. Publishers: Publication Press Inc., 200, North Bentalou Street, Baltimore 23, Maryland, U.S.A.

SHIP AND BOAT BUILDER
Year Book, 1952. Publishers: John Trundell (Publishers) Ltd., Temple Chambers, Temple Avenue, London, E.C.4. Price: 30s.

***STEEL FOUNDERS' SOCIETY OF AMERICA**
(1) Fundamentals of steel castings design; by C. W. Briggs. **(2) General engineering types of steel castings classified according to tensile strengths. (3) Cast weld construction,** by J. O. Felt. **(4) Developments concerning the properties of cast steels. (5) The steel castings industry.** Publishers: Steel Founders' Society of America, 920, Midland Building, Cleveland 15, Ohio, U.S.A.

***TIN RESEARCH INSTITUTE**
Report of the Tin Research Institute for 1951. Publishers: Tin Research Institute, Fraser Road, Greenford, Middlesex.

TRADE CATALOGUES

BIRLEC LTD.
Induction heating for forging. High frequency induction heating: clean, rapid heating for forging and upsetting, the "machine tool" approach to localised heat treatment, the "machine tool" approach to surface hardening. Address: Tyburn Road, Erdington, Birmingham, 24.

(*continued on page* 94)

Abstracts from Recent Welding Literature

(Compiled by J. L. SANDERS)

THIS section of *Transactions* makes no pretension to completeness but is intended only to provide readers with particulars of some of the more interesting papers appearing in recent welding periodicals.

Readers who need a complete survey should consult the *Bibliographical Bulletin for Welding and Allied Processes* published quarterly by the International Institute of Welding. Particulars may be had from the Secretary of the Institute.

Publications mentioned in the lists below are available on loan to members of the Institute and borrowers will facilitate matters if they will quote the appropriate reference number printed beside each entry.

ARC WELDING.—Electrodes

1588. ANON.
Modern methods for producing arc welding electrodes
Machinery Lloyd, vol. 24, 1952, Mar., pp. 91-93
The author describes the construction and principle features of an extruding plant for applying the coatings to electrodes having diameters between 14 s.w.g. and $\frac{1}{8}$ in. The average output is 20,000 electrodes per hour.

ARC WELDING.—In Inert Atmospheres

1589. GIBSON, G. J. and SEITZ, R. O.
Thoriated-tungsten electrodes: their welding characteristics and applications
Welding J., vol. 31, 1952, Feb., pp. 102-108.
From a consideration of basic arc theory, the authors show the difference between pure and thoriated tungsten electrodes. Tests were carried out to investigate arc starting characteristics, arc voltage, and electrode current carrying capacity, and it is stated that arc striking is simpler, arc voltage lower, electrode current-carrying capacity increased, weld contamination less troublesome, and electrode consumption considerably reduced when the thoriated type of electrode is used. The greatest advantages are gained when using D.C. supply, and these apply to the welding of stainless steel, copper, carbon steel, titanium, etc.

1590. MOEN, W. B. and GIBSON, G. J.
Schlieren analysis of inert-gas arc shields
Welding J., vol. 31, 1952, Mar., pp. 208-213
The schlieren method of making gases visible was applied to a comparison of helium and argon as arc shields with non-consumable electrode equipment. The results indicate that either gas will provide adequate coverage and the choice of gas depends only upon the desired electrical characteristics and economies. A brief explanation of the schlieren apparatus applied to this study and a number of photographs substantiating the results are included.

(Authors' Abstract.)

1591. PILIA, F. J.
"Contour" Arc Welding
Welding Eng., vol. 37, 1952, Apr., p. 54
In the inert-gas-shielded arc welding equipment described, an arc is struck between a tungsten electrode and the work and a filler wire is fed automatically into the arc. The motion of this filler wire also drives the torch along the seam. The advantages claimed for this system are: the ability to weld irregularly shaped objects, high welding speed (up to 100 in. per minute), and little skill is required on the part of the operator, who has only to guide the torch along the joint. Several applications are given.

ARC WELDING.—Twin-Arc

1592. WALLER, W. D.
The twin-arc process
Welding and Metal Fab., vol. 20, 1952, May, pp. 162-168
The twin-arc plant consists of a 3/2 phase transformer which draws a balanced load from the mains at a high-power factor, and a specially designed electrode holder for the twin-cored electrodes. Welding speeds are stated to be 100 per cent. faster than those obtainable with single-phase equipment and high quality welds are claimed. Only mild steel electrodes are available at present, but it is possible to use two standard electrodes fixed together in certain cases where other types are required. The welding technique is given for flat fillet, horizontal-vertical fillet (single and multi run) and butt welds. A comparison of welding costs is made between the single and twin-arc systems for a range of fillet weld sizes laid down in the flat position.

BRAZING

1593. ROSE, A. S.
Titanium aids silver brazing
Iron Age, vol. 169, 1952, Mar., pp. 96-97
The inability of titanium to become wetted by silver solder is used in the salt bath brazing of a stainless steel assembly. Strips of titanium around the assembly hold the molten solder in place until the stainless steel has reached brazing temperature. The strips have to be replaced after twenty-five hours exposure to the salt bath.

FLAME CUTTING

1594. ELLY, L. P.
Heavy scrap cutting in the steel mill
Welding J., vol. 31, 1952, Feb., pp. 97-101
This article describes a large cutting machine constructed for cutting scrap in thicknesses up to 60 in. to a size suitable for charging. The area covered by the cutting head is 10 ft. × 80 ft., and all motions are motor driven and remotely controlled. The machine is operated by one man and it is claimed that it is more economical than the lancing and blasting technique previously employed.

1595. YOCH, A. H.
Oxygen cutting of defence equipment materials
Welding J., vol. 31, 1952, Mar., pp. 217-230
It is necessary in certain cases to take special precautions when flame cutting alloy steels to prevent dangerous metallurgical changes occurring. This article sets out recommended procedures and gives details of the heat treatment which should be applied to alloy steels containing more than 0·3 per cent. carbon. Practical information is given on the flame cutting of a variety of components, an interesting example being the cutting of a pinion and gear ring for a 50-ton crane, no subsequent machining being necessary.

METAL SPRAYING

1596. HENZLIK, W. C.
Metallizing a Viaduct
Welding Eng., vol. 37, 1952, Mar., pp. 40-42
This viaduct was sprayed at site with an aluminium coat 0·008 in. thick and sealed with a coat of vinyl plastic. The author describes the preparation and spraying techniques and it is claimed that the structure is now protected for 25 years. 25,000 square feet of surface were protected using 3,000 lb. of aluminium, and it is stated that the vinyl sealing technique is more economical than spraying a thicker coat of aluminium to attain the same corrosion resistance.

1597. TOUR, S.
Modern developments in metallizing
Welding J., vol. 31, 1952, Mar., pp. 199-207
The development of the metal spraying process is outlined and improvements in the gun and its associated equipment noted. The following methods of surface preparation, and their relative merits are considered: sand and grit blasting, rough threading,

Meduna process, molybdenum bonding and steel flash bonding. The development of coatings having heat and corrosion resistance is described. The determination of the strength of sprayed coatings and of the bond between coating and base metal has necessitated the introduction of special tests and the importance of determining the internal stresses is emphasized. In the cases of sprayed aluminium and zinc, tensile strengths are claimed to be greater than that of the cast or wrought material. The strength of the bond between coating and base metal may be as high as 3,000 pounds per square inch in tension, and 10,000 pounds per square inch in shear. A section at the end of this article deals with corrosion protection and mentions the test programme being planned by the A.S.T.M.

RESISTANCE WELDING

1598. HIPPERSON, A. J. and KEEFE, E. J.
Resistance welding
Metal Ind., vol. 80, 1952, Apr. 11, pp. 283-286; Apr. 18, pp. 306-307
The high electrical and thermal conductivity of copper make it and its high alloys difficult to resistance weld except by the butt and flash-butt processes. Precautions to be taken when spot welding copper, silicon bronze, phosphor bronze and brass are given. Seam welding, projection welding and resistance brazing are briefly covered. In Part 2 the use of butt and flash-butt welding in the wire industry is described and it is noted that flash welding produces the best results. A special portable butt welding machine used for making joints in stator windings is illustrated.

RESISTANCE WELDING.—Butt and Flash

1599. COOPER, J. H.
Flash welding of components for aircraft and similar applications
Welding J., vol. 31, 1952, Feb., pp. 109-115
Flash-welded components for aircraft are allowed a maximum design ultimate stress equal to 80 per cent. of the minimum ultimate stress of the parent metal. Many examples of flash butt welded components are given. The greater confidence now placed in these assemblies has been achieved by improvements in control, instrumentation, inspection, testing, and the specific design of the component for welding.

RESISTANCE WELDING.—Projection

1600. NIPPES, E. F. and GERKEN, J. M.
Projection welding of steel in heavy gauges and in dissimilar thicknesses
Welding J., vol. 31, 1952, Mar. Supp., pp. 113-125
In this investigation the effects of weld current, weld time, electrode force and projection dimensions on weld formation and weld quality were studied. When welding both the 0·187 in. steel and the 0·250 in. to 0·250 in. steel, it was necessary to increase the electrode force at the termination of the weld current to minimise porosity. In addition, it was necessary either to apply an increased electrode force at the beginning of the weld, or to start the weld current at a low value to prevent flashing of the projection when the weld was initiated. The projection dimensions were not critical in their effect on weld quality. When welding 0·040 in. steel to thicker gauges, the same projection dimensions and electrode force used to weld 0·040 in. to 0·040 in. steel could be employed. However, the welding current and weld time had to be increased as the thickness of the thicker sheet was increased. A more uniform weld strength over the recommended current range resulted when the projection was placed in the thicker sheet rather than in the thinner sheet.
(Authors' Abstract.)

RESISTANCE WELDING.—Spot and Seam

1601. HIPPERSON, A. J.
Quality control of spot welded assemblies
Welding and Metal Fab., vol. 20, 1952, Mar., pp. 99-102; Apr., pp. 143-145
The author reviews the British Standard Specifications dealing with spot welding machines and notes that they encourage the employment of machines which do not rely on the skill of the operator. Published data on optimum machine settings should be used as a guide when beginning a new job, and the author emphasises the importance of instrumentation in order that the settings may be quickly transferred to the machine. Variations in weld strength are related to variations in current, time and electrode pressure, and means for their compensation noted. In Part 2 the author deals with the importance of the relationship $D = \sqrt{t}$, where D = electrode tip diameter in inches and t = thickness in inches of the thinnest component, and states that electrodes should be changed when the tip diameter has increased by one-third. The routine tests which should be applied and the application of statistical control methods are described.

1602. SLADE, C. E. and ZELLER, F.
Assembly by multi-point spot welding
Welding and Metal Fab., vol. 20, 1952, Apr., pp. 136-142
This article describes a multi-point spot welder recently completed for a motor car manufacturer which is used in the production of bucket seats, in which there is a total of 110 spot welds per seat. The machine, which is fully automatic, employs unskilled labour and welds one seat every forty seconds. The costs of this type of equipment are compared with that of using a number of separate machines, and it is claimed that a decrease of 56 per cent. in production costs may be obtained.

1603. SOLOMON, J. L.
Welding of high heat-resistant materials
Welding J., vol. 31, 1952, Mar., pp. 233-238
Brief notes on the construction of the gas turbine engine are given showing the use of mild steel, stainless steel, the nickel base alloys and titanium in its construction. The effect of the electrical, physical and mechanical properties of these materials on the welding procedure is shown. The use of three-phase equipment is recommended, as for reasons shown, the operating conditions are less critical than with single phase.

SURFACING

1604. AVERY, H. S.
Hard facing for impact
Welding J., vol. 31, 1952, Feb., pp. 116-121
Wear, defined as deterioration due to use, is caused primarily by mechanical, chemical and thermal factors. The mechanical factors operate through stress, and impact is one of the important stress producers. Hard facing, which is one of the important techniques for combating wear, can provide effective protection against deterioration from impact provided the alloys are properly selected and used. The most appropriate hard-facing materials for such service are martensitic irons, martensitic steels, and austenitic steels; which are considered suitable for light, medium and heavy impact respectively. In this article static and dynamic compression testing are described, together with data on important hard-facing alloys, while the importance of design to avoid tension is stressed. Critical limitations of impact energy and velocity are suggested to minimize structural damage and to help in alloy selection. The three hard-facing alloy types are described in some detail to guide the engineer in their selection. A few representative applications are given and the advantage of composite structures in wear control is shown. This paper is intended to help engineers cope with the problems of industrial wear and includes some data on abrasion. (Author's Abstract.)

TESTING.—Low temperature

1605. EVERHART, J. L.
How to select steels for low temperature service
Materials and Methods, vol. 35, 1952, Jan., pp. 75-79
Steels which are suitable for service at normal temperatures may be unsuitable for low temperature service. Some will prove satisfactory under static loading, but will fail if dynamically stressed. The author states that some correlation has been found between the Charpy and full scale plate tests and describes how the selection of steel is affected by both metallurgical and mechanical factors. Tables of mechanical properties of a number of steels at temperatures down to −320 deg. F., the effect of sustained stress at this temperature and the effect of melting practice on impact values are given. The effect of welding is briefly covered and a number of types of steel for temperatures between room and −200 deg. F. are suggested.

TESTING.—X-Rays

1606. MULLINS, L.
Radiography in Engineering
Machinery Lloyd, vol. 24, 1952, Feb., pp. 69-81
The author deals first with the principles of X-ray generation and compares properties with those of gamma-rays. The choice of equipment to suit various applications is described and attention is drawn to the limitations of radiographic inspection. The principles involved in making the radiograph are discussed and practical information on the radiography of welds and castings is given.

TESTING.—Weldability

1607. FELIX, W. A.
The practical testing of the cohesive strength and weldability of steels
Welding J., vol. 31, 1952, Feb. Supp., pp. 105-111
The author describes the testing methods in use at a large Swiss engineering works to assess the cohesive strength and weldability of steels used in highly stressed welded structures.

WELDABILITY.—Non-ferrous.—Copper Alloys

1608. SPENCER, L. F.
Welding procedures for copper-base alloys
Welding Eng., vol. 37, 1952, Mar., pp. 17-22; Apr., pp. 42-46, p. 48
In Part 1 the types of joints recommended for different gauges of material are shown and the use of different types of backing bars is explained. A table showing the proposed AWS-ASTM classification of copper and copper alloy electrodes is given. The fusion welding of copper (tough pitch and deoxidised), beryllium copper and the brasses is then described. In Part 2 the fusion welding of silicon bronzes, aluminium bronzes, phosphor bronzes, and nickel bearing alloys is covered and in each case the merits of the various fusion welding processes are described. A table sets out the procedures for welding silicon bronze in thicknesses from 1/16-¾ in. by the carbon arc and the oxy-acetylene processes. The author deals finally with the resistance welding of a range of copper alloys, and their weldabilities are summarised in a table. It is noted that weldability is inversely proportional to the electrical and thermal conductivity of the material.

WELDABILITY.—Non-ferrous.—Titanium

1609. SEGARD, J.
Titanium takes a test
Welding Eng., vol. 37, 1952, Mar., pp. 24-27
Tests carried out by Ryan Aeronautical Company show that titanium may be fabricated in a manner similar to stainless steel. It has been found impossible, however, to weld titanium to any other metal. Up to 800 deg. F. titanium alloys maintain their high strength, but when held above this figure for long periods, their strength falls off rapidly. It is considered that this is due to the surface absorption of oxygen and the possibility of providing a ceramic coating to overcome this is mentioned.

WELDED CONSTRUCTION.—Buildings

1610. JEFFERSON, T. B.
Houston's new welded office building
Welding Eng., vol. 37, 1952, Mar., pp. 35-37
This is a brief description of a 22-storey all-welded steel framed office building.

WELDED CONSTRUCTION.—Design

1611. NEAL, B. G. and SYMONDS, P. S.
The rapid calculation of the plastic collapse load of a framed structure
Proc. Inst. C.E., vol. 1, 1952, Apr., pp. 59-100
A framed structure of ductile material, such as mild steel, collapses when the applied loads are increased to such values that a sufficient number of plastic hinges are formed to transform the structures into a mechanism, which can then continue to deform under constant load. For complicated frames the determination of the positions of the plastic hinges, and thus of the collapse load, may become very lengthy by existing methods. The paper presents a new method of determining the plastic-hinge positions and the corresponding value of the collapse load, which is considerably shorter than methods described previously.
(Authors' Abstract.)

WELDED CONSTRUCTION.—Gas Holders

1612. KNIGHT, G. F.
Toronto's all-welded gasholder
Welding Eng., vol. 37, 1952, Feb., pp. 30-33, p. 37
The author describes the construction of a 5 lift, 10 million cu. ft. capacity gasholder, and gives details of stress relieving treatment, inspection, testing and erection procedure.

WELDED CONSTRUCTION.—Machinery

1613. ANON.
Better dipper sticks by submerged-arc welding
Welding Eng., vol. 37, 1952, Mar., pp. 32-34
Describes briefly the construction of all-welded tubular dipper sticks for use on excavating equipment.

1614. ANON.
Fabricated deep-drawing press
Welding and Metal Fab., vol. 20, 1952, May, pp. 158-161
This press is capable of exerting a ram force of 1,000 tons and a force of 200 tons on the blankholder. Information on the working cycle, speed of operation, controls and applications and details of welding procedure, preheating and stress relieving used in its construction are given.

1615. CLASON, C. B.
From sheet metal to home freezers
Welding Eng., vol. 37, 1952, Apr., pp. 23-27
This article outlines the application of welding and brazing to the construction of refrigeration equipment.

1616. OBRINGER, E. and MONTANUS, R. C.
It's steel for shock resistance
Welding Eng., vol. 37, 1952, Feb., pp. 27-29, p. 42
Stresses sufficient to cause the failure of a lathe of conventional cast iron construction are encountered aboard ship due to deck weaving and bombing. The authors describe a lathe designed to resist these stresses which employs a welded steel bed and legs of special construction to prevent torsional stresses warping the guiding surfaces.

1617. RHEINGANS, W. J.
Welded plate steel for Francis turbines
Welding Eng., vol. 37, 1952, Apr., pp. 36-39
The author discusses the advantages of welded steel casings for large water turbines, and shows that an overall saving in cost of 13 per cent. is obtainable when compared with the cost of a cast structure. Field welding has not been permitted in many installations, but several exceptions to this are noted and briefly described, and mention is made of a new low temperature method of stress relieving welds *in situ*. Stainless steel and stainless steel clad runners are stated to be superior to those in mild steel and stainless steels containing 12 to 14 per cent. chromium have better erosion resistance than 18/8. It is noted that aluminium bronze is a very promising material for use in hydraulic equipment as it possesses good resistance to both cavitation and erosion.

WELDED CONSTRUCTION.—Petroleum Industry

1618. ANON.
Extension at the Llandarcy refinery
Welding and Metal Fab., vol. 20, 1952, May, pp. 169-173
Describes the procedures and precautions adopted in training and testing operatives and in maintaining weld quality. Some of the equipment under construction is briefly described.

WELDED CONSTRUCTION.—Pressure Vessels

1619. ARNE, C.
The Horton multisphere
Welding J., vol. 31, 1952, Feb., pp. 146-147
The multisphere is a pressure vessel consisting of a number of intersecting spheres and is claimed to withstand twice the pressure of a cylindrical vessel having the same wall thickness. Two such vessels in service are illustrated and working details given.

1620. HARRIS, H.
The welding of pressure vessels
West of Scotland Iron and Steel J., vol. 58, 1950-51, pp. 11-48
The author surveys the progress made in pressure vessel construction and discusses the metallurgical problems associated with the use of very heavy plate in their construction. The use of supersonic testing equipment in the detection of flaws in the plate prior to fabrication is described. Automatic arc welding equipment is now extensively used and a propane or butane shroud around the arc is employed in addition to that provided by the coating; by reducing the sulphur content of the core wire to 0·015 per cent. max. the rate of detection of defects was reduced from 157 ft. of welding per defect to 477 ft. of welding per defect. The possibility of using higher tensile steel plate is discussed and the test requirements imposed on small pressure vessels are criticised. A preliminary supersonic examination of the welded seams to determine those areas containing defects is claimed to effect a considerable saving in radiographic costs.

WELDED CONSTRUCTION.—Repairs

1621. BERNHARD, E. E. N. and DIXON, P. A.
Outstanding welding repairs on hot blooming mill shears
Welder, vol. 21, 1952, Jan.-Mar., pp. 2-7
The authors describe in considerable detail the repair of a 16 ton casting of composition 0·35 per cent. carbon, 0·42 per cent. chromium and 0·31 per cent. nickel by arc welding. After repairing the main crack it was found that numerous other fine cracks had opened up considerably. Following a consideration of the methods of repairing these cracks it was decided to try the "barrier system." This consists of laying down a number of weld barriers at intervals to prevent the cracks spreading, afterwards opening up the cracks for welding. The authors claim that this technique has proved very satisfactory and has since been used with equal success on other repair jobs.

1622. SOMERS, R. E. and VON BLOHN, H. C.
Surface conditioning of structural steel
Welding J., vol. 31, 1952, Mar., pp. 193-198
Following a survey of the development of methods of repairing surface defects in rolled steel, the causes of underbead cracking in structural silicon steel are explained and a description of comparative tests on welds made with mild steel and low hydrogen electrodes is given. It is stated in conclusion that underbead cracking may be eliminated by the use of the low hydrogen type of electrode and that the A.S.T.M. Specification for 1950 permits its use for repairing defects in the A.94 silicon steels.

WELDED CONSTRUCTION.—Ships

1623. ANON.
Failures in welded ships
Welding and Metal Fab., vol. 20, 1952, Apr., pp. 130-134
This article describes the conditions which led to the failure of several American welded ships and shows how investigation and research work have demonstrated the factors which caused failure. Improved materials, workmanship and design now ensure a reliable structure and it is encouraging to note that no welded ships built in Great Britain since 1945 have failed.

1624. CAMPBELL, W. R., IRWIN, L. K. and DUNCAN, R. C.
Stress studies of bulkhead intersections for welded tankers
Welding J., vol. 31, 1952, Feb. Supp., pp. 68-77
Four large bulkhead intersection specimens were tested in tension in the Engineering Mechanics Section of the National Bureau of Standards for the Ship Structure Committee. The tests are part of a study of the typical structural discontinuities in ships to determine the magnitude of stress concentrations and areas affected by discontinuities, and to furnish data necessary for improving current designs. Each specimen represents the intersection of a longitudinal bulkhead and a transverse bulkhead as found in welded tanker design. The elastic stress distribution at room temperature, strain distributions prior to failure at 0 deg. F. and energy for failure at 0 deg. F. are presented. Stress values in the region of the intersection are compared with stresses in the longitudinal bulkhead bordering the intersection. Stress concentrations and energy at failure for the different specimens are also compared.
(Authors' Abstract.)

1625. CORLETT, E. C. B.
Aluminium as a shipbuilding material
Trans. N.E. Coast Inst. Eng. and Shipbuilders, vol. 68, 1952, Mar., pp. 221-248
The North-East Coast Institution has a pioneer interest in the development of aluminium as a shipbuilding material, and this paper is, in effect, a report of practical progress to date. Materials and their present status, the methods available for joining them, and future trends are discussed in the first section, and in the second, the outline of a code of practice is sketched. A new set of sections is proposed and the geometric properties of such a range given. Scantling tables for deckhouses and light superstructures are proposed and a set of such tables put forward. While these tables are tentative, the weight ratios obtained are attractive, offering possible material savings. Details of the use of aluminium in the new liner *United States* are given.
(Author's Abstract)

WELDED VERSUS CAST CONSTRUCTION

1626. BROOKE, M. S.
Welded fabrication replaces cast construction
Commonwealth Eng., vol. 39, 1952, Jan., pp. 240-243
The author describes how welded fabrications have replaced cast structures in the manufacture of an excavator, rock-crusher, etc.

WELDERS.—Safety and Health

1627. BATES, C. C.
The effects on the human eye of the radiant energy given off by various welding processes
Sheet Metal Ind., vol. 29, 1952, Apr., pp. 349-352, p. 357; May, pp. 435-440, p. 447
The author describes first the structure of the human eye and notes those parts which are affected by the radiation from the welding processes. The effect of infra-red and visible radiations are examined. Prolonged exposure to the former may result in serious injury to the lens, and, in certain cases, heat cataract may occur. Exposure to the visible wave lengths produces no permanent injury but may cause considerable discomfort and pain to the operative, and its intensity should be reduced by a suitable filter to a comfortable working level. In Part 2 the effect of ultra-violet radiation is examined and it is noted that no permanent injury has been detected as a result of short exposure, provided that adequate treatment is obtained. The causes of "Arc-Eye" are set out and recommended treatments given. The selection of the correct filter for a given operation is most important and it is recommended that operatives working in the vicinity of welding operations should be protected by special goggles.

LATEST ADDITIONS TO THE LIBRARY—*continued from page 90*

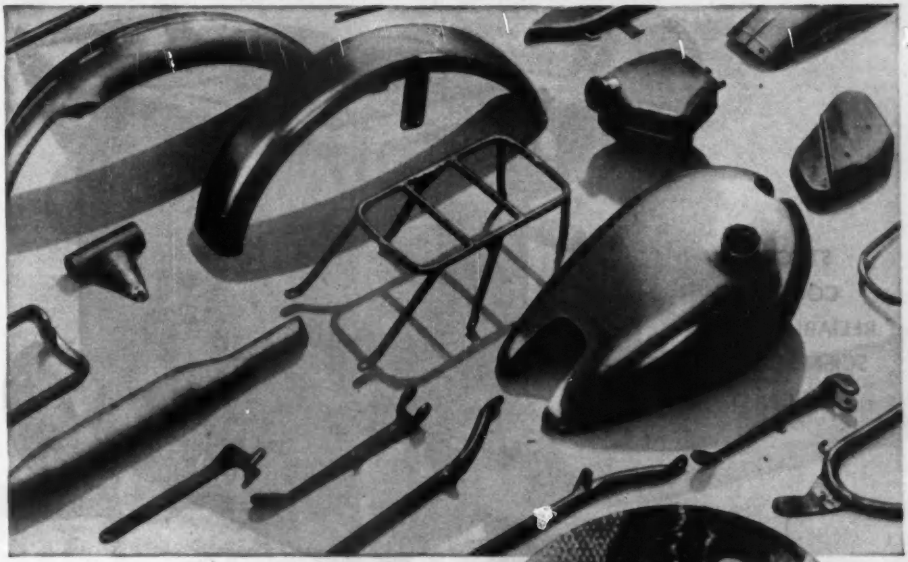
BRITISH ELECTRONIC PRODUCTS (1948) LTD.
Electronics for industry. B.E.P. equipment for resistance welding control. Specification for ignitron contactor units. Specification for ignitron weld heat control. Specification for synchronous weld timers. Address: Rugeley, Staffordshire.

BRITISH THOMSON-HOUSTON CO. LTD.
Electrical machinery and apparatus, which include electronic control equipments for resistance welding machines, electronic-magnetic contactors, ignitrons, thyratrons and rectifiers, electronic induction heaters, etc. Address: Rugby.

EUTECTIC WELDING ALLOYS CORPORATION
1951-52 Eutectic directory. (Data on low temperature welding alloys.) Address: 172nd Street and Northern Boulevard, Flushing, New York, N.Y. Agents: Eutectic Welding Alloys Co. Ltd., 156 and 158, Abbey House, Victoria Street, London, S.W.1.

A. H. WILKES & COMPANY
Industrial gas appliances, which include soldering furnaces, soldering iron heaters, accessories, gas heated soldering irons, brazing equipment, and blowpipe accessories. Address: Alcosa Works, Stourport-on-Severn, Worcs.

J. H. WILLIAMS & CO.
The Saxe Welded erection system. Address: 400, Vulcan Street, Buffalo 7, New York.



70 M.P.H. JIGSAW!

OXY-GAS WELDING

steps up motor cycle production

Planning based on oxy-gas welding of components saves production time, while assuring strength and a neat finish to each component. Many British motor cycles are made on this principle, as our illustrations show. Much of their renowned quality and stamina rests on the high efficiency of B.O.C oxy-gas welding techniques.

For further details, please write to:

SERVICE EXCHANGE SYSTEM

Users of B.O.C equipment should take advantage of the Service Exchange System. B.O.C equipment in need of repair may be exchanged at your local branch for re-conditioned equipment at purely nominal cost.

BOC **THE BRITISH OXYGEN CO LTD**

LONDON AND BRANCHES

STRONG,
COMPACT,
RELIABLE UNITS,
SCIENTIFICALLY
DESIGNED.

Single Operator Welding Sets

by

G.E.C.

Send for Booklet P9556

THE GENERAL ELECTRIC CO., LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

Some of the various types of B.G.T. cutting nozzles.

A special Oxy/Propane heating nozzle.

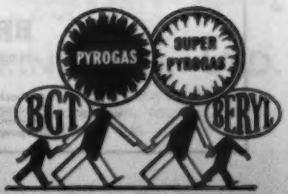
BGT

B. G. T. supply a complete range of cutting and heating nozzles for every purpose: annulus and splined (self-centering) types for acetylene, propane or hydrogen.

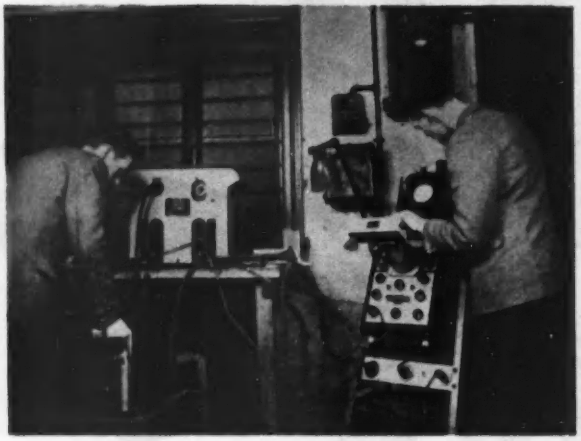
BRITISH GAS AND TORCH CO., LTD.

HEAD OFFICE: DOWNSHIRE HOUSE, ROEHAMPTON LANE, LONDON, S.W.15.
PUTney 3742. PYROGAS, PUT, LONDON.

Branches: BIRMINGHAM · GLASGOW · LONDON · MANCHESTER
SOUTHAMPTON (Lymington) · SUNDERLAND · SHEFFIELD
THORNABY-on-TEES.



ONE REASON FOR Cyc-Arc STUD-WELDING RELIABILITY



Timing a sequence with a Cossor double beam oscillograph in our research department

is unceasing and painstaking research.

That is why Cyc-Arc equipment will weld Steel, Brass, Aluminium Studs and details SPEEDILY, SECURELY, ECONOMICALLY

We will be glad to send full information

Cyc-Arc

27-29 NEW NORTH RD. LONDON, N.1

When you think of control...

Strings, woodwind, brass all under control by a movement of the finger or a flick of the baton. Likewise control of compressed gases is essential for harmony in use, so . . .

. . . think of REGULATORS by BIG

'The orchestra speaks'

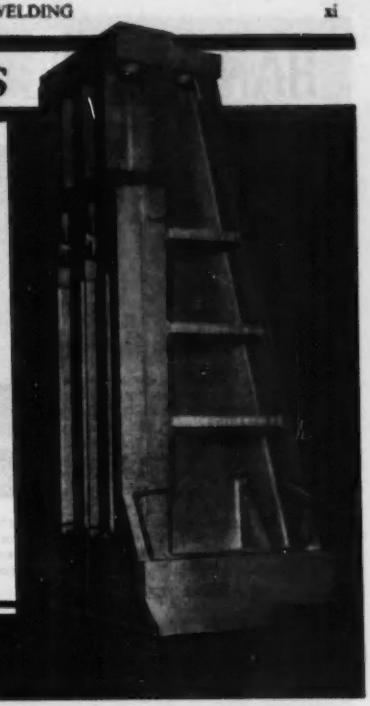
BRITISH INDUSTRIAL GASES LTD.

Head Office: 32 VICTORIA STREET, LONDON, S.W.1

Telephone: ABBey 6082/3 and 4

WORKS			
London:	Eastway, Hackney, London, E.9	Telephone:	Amherst 5443/4
Manchester:	Richmond Road, Trafford Park, Manchester, 17	Telephone:	Trafford Park 1041/2
Liverpool:	Fleming Road, Speke, Liverpool, 19	Telephone:	Hunts Cross 1212/3
Glasgow:	Queen Elizabeth Ave., Hillington, Glasgow, S.W.2	Telephone:	Halfway 1651

WELDED MACHINE FRAMES



ADVANTAGES OF WELDED CONSTRUCTION.

Thickness under accurate control.

Less machining needed.

No blow-holes, hard spots or fused-in-sand to hinder machining.

Exceptional ductility, reducing risk of failure through localized stress.

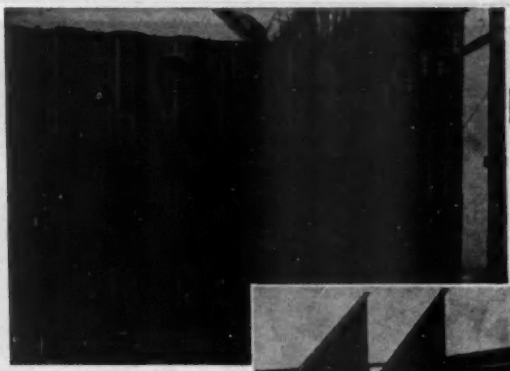
Reduced weight with greater strength.

No porosity or weakness at junction of walls, even if plates are of unequal thickness.

Lower cost.

DORMAN LONG & CO. LIMITED,
Welding Department,
REDCAR, YORKS.
Telegrams: Redcast, Telex, Middlesbrough. Telephone: Redcar 171
London Office: 52, Grosvenor Gardens, S.W.1

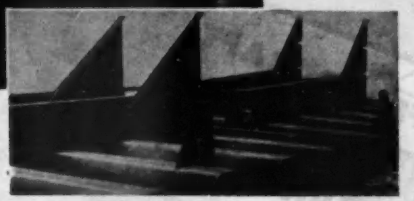
DORMAN LONG



Photograph by courtesy of Bartram & Sons Ltd.

Pressed Steel Troughing is used by the leading Shipbuilders in the Tyneside and Clydeside areas.

EGYPT—
The Port Said Engineering Works, Port Said



Large illustration: TRANSVERSE BULKHEAD IN POSITION
Small illustration: BULKHEADS WITH GIRDERS AND WEBS ATTACHED READY FOR ERECTION.

PRESSED STEEL
Troughing
FOR SHIPS' BULKHEADS

Sections of Troughing pressed from Steel Plates are found in actual practice to be superior to the old method of welding steel plates together. Here are six specific advantages:—

● Saves up to 20% steel weight. ● Reduces labour costs. ● No comparative sharp corners to damage cargo. ● Fewer edges where corrosion can begin. ● Smooth surface throughout which is easy to clean, scrape and paint. ● Suitable for transverse, longitudinal and 'tween-deck bulkheads.

Troughing is supplied in lengths up to 30 feet.

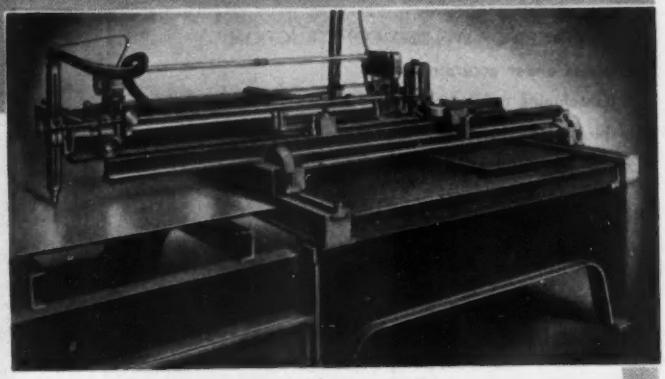
MOTHERWELL BRIDGE & ENGINEERING CO. LTD.

Telegrams: BRIDGE, MOTHERWELL
Telephone: MOTHERWELL 40, 41, 42

HEAD OFFICE AND WORKS:
MOTHERWELL

London Address: 52, VICTORIA STREET, S.W.1
Telegrams: HOBRICOLPH, SOUWEST, LONDON
Telephone: VICTORIA 4183

HANCOCK L.P. CUTTING MACHINE



reduces cutting time on large areas

The L.P. Machine is made in four standard sizes with cutting widths of 3ft., 5ft., 7ft. and 10ft. the length in each case being 10ft. this length can be extended to 50ft. or more by additional lengths of rail. A second carriage can be fitted when the machine virtually becomes two machines working simultaneously on the same or two separate plates. All machines use the exclusive Universal Tracer Head available with six alternative drives including an Electronic Drive for completely automatic tracing from a black and white drawing. These profilers are particularly suited for large components such as locomotive frames, ships' plating, plating for mono-ferric construction, etc., where great overall accuracy is required.

HANCOXYGEN cutting is best. *Write for 28 page illustrated catalogue today.*

HANCOCK & CO., (Engineers) LTD

PROGRESS WAY, CROYDON, SURREY, ENGLAND *Telephone:* CROYDON 1968

HANCOCK CUTTING MACHINES

ALICRAFT
HARDCRAFT
STEELCRAFT
FERROCRAFT
BRONZECRAFT
for craftsmen who want the best
Here is an outstandingly good range of oxy-acetylene Welding Rods—ALIcraft for aluminium and alloys, HARDcraft for hard surfacing, STEELcraft for mild steel and iron, BRONZEcraft for bronze-welding. They will give you consistently reliable welds. Full details and prices are available on request.
WELDCRAFT LTD
PROGRESS WAY · CROYDON · ENGLAND Phone: CROydon 1908 (PBX)

Industrial Liquids

in welded tanks

Above: 750-gallon single-compartment mild steel tank for gas-oil. Fitted with pump-discharge.

TRANSPORT of industrial liquids has become more and more a job for road tanks — and Butterfield Road Tanks in particular.

The strength of the tank, and its welded joints, is frequently tested on roads that are far from good.

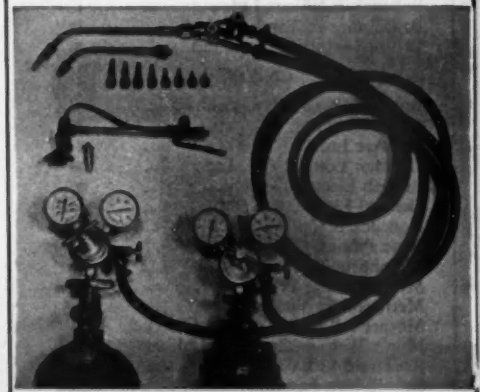
It is then that Butterfield craftsmanship shows its worth. Up and down the roads, overseas as well as at home, Butterfield Road Tanks are proving their ability to do all that is expected of them, and more.

Fabricated in Stainless Steel, Mild Steel and Aluminium

BUTTERFIELD
ROAD TANKS

W. P. BUTTERFIELD LTD., SHIPLEY, YORKS. Tel: 52244 (7 lines)
LONDON: AFRICA HOUSE, KINGSWAY, W.C.2. Tel: HOLborn 1449

OUR LATEST PATTERN
WELDING & CUTTING APPARATUS



CATALOGUE ON APPLICATION TO
THORN & HODDLE LTD.,
151, VICTORIA STREET, LONDON, S.W.1
Telephone: VICTORIA 3773 Telegrams: INCANTO, SOWEST, LONDON

B T-H
IGNITRONS
—HIGH-SPEED HEAVY-CURRENT ELECTRONIC "CONTACTORS"

A complete range for use in Electric Resistance Welding Equipment

RATINGS AT 440 VOLTS					
DUTY CYCLE	3%	10%	25%	50%	75%
IGNITRONS	kVA	kVA	kVA	kVA	kVA
TWO BK 66	300	158	80	44	28
TWO BK 42	600	361	202	110	73
TWO BK 24	1,200	836	475	268	176
TWO BK 34	2,400	1,976	1,100	691	440

Interchangeable with American Ignitrons sizes A.B.C.D. without modification to your equipment.

THE **BRITISH THOMSON-HOUSTON** COMPANY LIMITED RUGBY ENGLAND
Member of the AEI group of companies

ELMET WELDING MATERIALS

FOR
ELECTRIC RESISTANCE WELDING

ELMET METALS
in different compositions
FOR ALL WELDING PROBLEMS
in Rods, Bars, Discs and Rings

STANDARD
SPOT WELDING
ELECTRODES
•
SEAM WELDING
WHEELS
•
UPSETTING DIES

Further information and quotations supplied on request

METRO-CUTANIT LTD
ASSOCIATED WITH METROPOLITAN-VICKERS ELECTRICAL CO LTD
160 PICCADILLY LONDON W1
Telephone: GROSVENOR 7121

Fourth Edition

Electric Arc and Oxy-Acetylene Welding

By the late E. Arthur Atkins, M.Sc., M.I.Mech.E., and A. G. Walker, M.Inst.W.; revised by W. A. Atkins, L.I.M., M.Inst.Met., M.I. & S.I., and A. G. Walker. This is a complete revision of a notable textbook and reference work. Widely used by students, operators and works managers, it is a sound and up-to-date guide to every aspect of the welder's craft. With 186 illustrations. 30s. net.

"The author may be congratulated on his method of dealing with the subject in this volume."—*Journal of the Junior Institution of Engineers.*

From booksellers. Published by

PITMAN, Parker Street, Kingsway, London, W.C.2

SIFBRONZE

This is the welding rod for all round service. It requires little or no preheating and can be used to weld all metals except aluminium. Sifbronze patented copper-zinc alloy rods are better because of their EXTRA constituents.

Write for full details today, also ask for free copy of "Self-Tips" magazine.

SUFFOLK IRON FOUNDRY (1920) LTD
SIFBRONZE WORKS, STOWMARKET, SUFFOLK
Telephone Stowmarket 183 (3 lines)

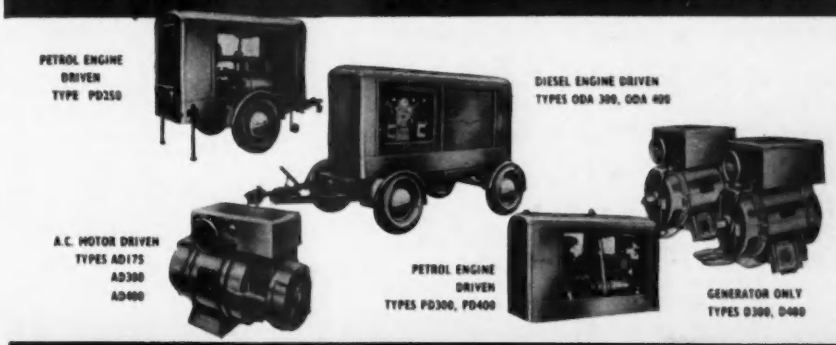
INDEX TO ADVERTISERS IN THIS ISSUE

	Page
Babcock & Wilcox Ltd.	i
British Gas & Torch Co Ltd. ..	ix
British Industrial Gases Ltd. ..	x
British Oxygen Co. Ltd.	Front cover and vii
British Thomson-Houston ..	xiii
Butterfields Ltd.	xiii
Cyc-Arc Ltd.	x
Dorman Long & Co., Ltd. ..	xi
English Electric Co. Ltd.. ..	v
General Electric Co. Ltd. ..	viii
Hancock & Co.	xii
Isaac Pitman	xiv
R. Johnson & Nephew Ltd. ..	iii
Metro-Cutanit Ltd.	xiv
Metropolitan Vickers Ltd. ..	ii
Motherwell Bridge & Eng. Co. ..	xi
Murex Welding Processes Ltd. ..	4
Rockweld Ltd.	3
Suffolk Iron Foundry	xiv
Thorn & Hoddle Ltd.	xiii
Tubewrights Ltd.	2
United Steel Cos.	iv
Weldcraft Ltd.	xii
Welding Supplies Ltd.	vi

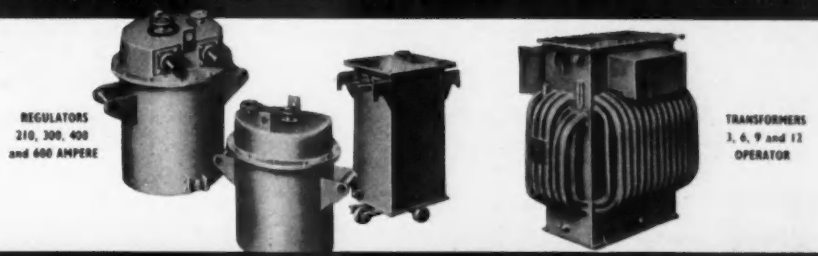
ROCKWELD

Arc welding electrodes for all purposes.
A.C. & D.C. welding plant of all types and capacities.
Welders' Accessories and general supplies for the welding shop.

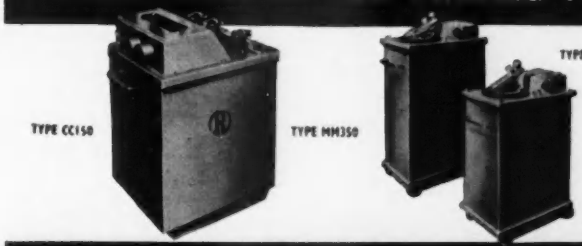
SINGLE-OPERATOR D.C. ARC WELDING PLANT


PETROL ENGINE DRIVEN TYPE PD250
DIESEL ENGINE DRIVEN TYPES ODA 300, ODA 400
A.C. MOTOR DRIVEN TYPES AD175 AD300 AD400
PETROL ENGINE DRIVEN TYPES PD300, PD400
GENERATOR ONLY TYPES D300, D400

MULTI-OPERATOR A.C. ARC WELDING PLANT



SINGLE-OPERATOR ARC WELDING TRANSFORMERS



Our Engineers are available for advice on the selection, arrangement and installation of these machines.

ROCKWELD LTD · CROYDON · SURREY TEL: CROYDON 7161 (5 LINES) GRAMS: ROCKWELD, PHONE, CROYDON

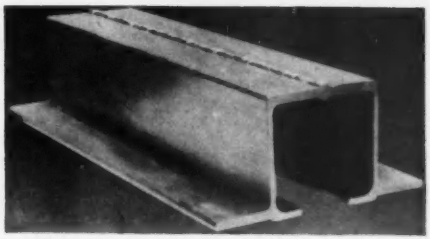
MUREX
ALUMINIUM 5% SILICON EXTRUDED ELECTRODES

Officially approved for welding aluminium alloys by the deep penetration method . . .

Murex aluminium 5% silicon electrodes have been specially developed for the arc welding of aluminium alloys, in which they can produce welds having high tensile strength—minimum 10·5 tons/sq. in. The electrodes may be used for deep penetration welding with currents up to 400 amps. D.C. for welding sections of thicknesses up to ½ in. without special edge preparation and without preheating.

The electrodes are of the plain extruded type and have the advantages of uniformity of coating and welding properties. They are smooth running, simple to use and while they are designed for downhand welding, they can also be used in all positions. Another feature is that the slag is easy to remove.

The electrodes are officially approved by the Ministry of Supply for welding military bridging equipment and they represent the latest advance in the arc welding of aluminium alloys.



An aluminium alloy section of ½ in. thickness welded with one run and a sealing run, using a No. 4 gauge Murex extruded aluminium silicon electrode without special edge preparation and without preheating.

ADVANTAGES

- ✦ *Officially approved by the Ministry of Supply for the welding of military bridging equipment.*
- ★ *High tensile strength welds—minimum 10·5 tons/sq. in.*
- ★ *For deep penetration welding—larger gauge electrodes can be used with currents up to 400 amps. D.C.*
- ★ *Aluminium alloys of thicknesses up to ½ in. can be welded without special edge preparation and without preheating.*
- ★ *Plain extruded type of electrode for uniformity of coating and welding properties.*
- ★ *Smooth running—simple to use—primarily a downhand electrode but can be used in all positions. Easy slag removal.*

ELECTRIC ARC WELDING **MUREX** EQUIPMENT & ELECTRODES

MUREX WELDING PROCESSES LIMITED, WALTHAM CROSS, HERTS. Telephone: WALTHAM CROSS 3636

T9

Printed in England by LAWRENCE PRESS LTD., Henry Road, New Barnet, Herts., and Published by The Institute of Welding, 2, Buckingham Palace Gardens, London. S.W.1. *June*, 1952.